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SURVEY OF LITERATURE ON THE ASSESSMENT OF THE POLLUTION POTENTIAL OF THE PEAT RESOURCE

BY

WASHBURN & GILLIS
ASSOCIATES LTD.

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ASSESSMENT OF THE POLLUTION
POTENTIAL OF THE PEAT RESOURCE

FINAL REPORT
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by
WASHBURN & GILLIS ASSOCIATES LTD.

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ABSTRACT

An extensive review of the information pertaining to the chemistry of peat and peat waters was conducted. Information was assembled from computerized literature surveys, conference proceedings, unpublished data, and discussions with provincial and federal government personnel and representatives from private industry, including consultants and peat producers. To facilitate future use of the data that has been compiled in this review, much of the data is presented in tabular form.

The inorganic chemistry of peats was found to be well documented, whereas less information is available about the chemistry of peat waters. No levels of specific organic contaminants in natural peat or peat waters were reported, with the exception of certain insecticide residues. Concerns with respect to environmental contamination from use of peat for energy pertained largely to release of metals into the environment during combustion, and impacts on water and air quality during peat harvesting operations. However no environmental criteria specific to the use of the energy peat resource were found. Widespread use of fuel peats in large developments in Canada appears unlikely in the near future, but some emphasis may be placed on projects to demonstrate the use of peat as fuel in remote areas.

Further information that is necessary for the development of environmental criteria for peat harvesting operations has been identified and methods for obtaining this information are suggested.

RESUME

Une critique approfondie de l'information concernant l'activité chimique de la tourbe et ses eaux fut menée. L'information fut assemblée de plusieurs sources: des enquêtes littéraires gérées par l'ordinateur, des comptes rendus de conférences, de l'information non publiée et des discussions avec des personnes du gouvernement fédéral, ainsi que provincial, et avec des représentants du secteur privé. Une grande partie de l'information fut présentée sous forme de tableau afin de faciliter l'usage de cette information comprise dans ce compte-rendu.

La chimie inorganique de la tourbe fut considérée comme étant bien documentée dans la littérature, tandis que l'information concernant la chimie inorganique de l'eau de tourbe ne fut pas aussi disponible. Aucun niveau de contaminants organiques qui sont naturellement présents dans la tourbe, fut rapporté sauf certain résidu d'insecticides. L'intérêt concernant la contamination environnementale, en utilisant la tourbe, fut principalement dirigé versle dégagement de métaux dans l'environnement pendant la combustion et les effets sur la qualité des eaux et l'air pendant la récolte de tourbe. Cependant, aucun critère environnemental, spécifique à l'utilisation de l'énergie de tourbe, fut trouvé. L'usage commun de la tourbe combustible au Canada semble improbable dans le futur proche mais l'accent pourrait être placé sur des projets qui démontrent l'usage de la tourbe comme combustible dans des régions isolées.

L'information nécessaire, pour le développement de critères environnementals concernant la récolte de la tourbe, fut identifiée et des méthodes pour obtenir cette information furent suggérées.

SUMMARY AND RECOMMENDATIONS

Material referenced pertaining to the chemistry of peat and peat waters consists for the most part of the results of field investigations in various parts of the world. Emphasis was placed on data which would be relevant to Canadian energy peat utilization, so where possible only that data pertaining to north temperate and northern latitudes was included.

The particular parameters defined in the literature reflected the interests of researchers and the variety of uses of the peat resource. There was extensive data on use of peat as a source of industrial chemicals. However, data from these sources related to the chemistry was developed following a variety of extraction procedures and so was not felt to be applicable to the natural peatland harvesting operations. A large body of data also exists on the chemistry of peat and peat waters from peatlands used for agriculture or forestry which have been enriched through the use of fertilizers or lime. For certain peat and peat water characteristics such as organic chemistry, these were the only sources available and so that data was included. However, for the most part, information from agricultural and forestry sources was not included.

Information sources used in this project included: Proceedings of the International Peat Congress, Peat Abstracts, Agricultural Abstracts, Bio Abstracts, Chem Abstracts, National Technical Information Service; Symposium on Peat as an Energy Alternative, Symposium on Management Assessment of Peat as an Energy Resource, and Publications from Minnesota Peat Program. Relevant references identified in this material were

obtained. Publications identified in these references were then identified and obtained. Although not a major difficulty, some problems occurred in getting access to some references not available in Canada.

Other information, much of which was unpublished, was obtained from provincial and federal government personnel and individual researchers in universities and private industry.

Information on the chemistry of peat and peat waters in Canada is scant, particularly with respect to parameters identified in the Water Pollution Control Directorate's list of toxic chemicals. Although the general trends described in chemistry of peat and peat waters would apply to Canada, predictions of potential site-specific chemistry based on the review is impossible due to the variability in factors affecting the density.

In view of the fact that inventories of the peat resources are being conducted in a number of provinces, and some pilot-scale fuel peat harvesting operations are planned in the near future, there is an opportunity to develop a background of site-specific information on chemistry of peat and peat waters in Canada. Particular emphasis should be placed on identifying trace organic contaminants. Levels of organic contaminants should be determined in water extracts from raw peat. Other parameters of particular concern would be the concentration of the various heavy metals found in peatlands. Water samples obtained from peat should be analysed, and more specifically monitored as a function of time. This concern is prompted by the fact that the rate of humate breakdown varies with both time and pH.

Potential pollutants which were originally absorbed by humates will most likely be leached into the surrounding water when humates break down.

In programs to determine the chemistry of peat or peat waters the following characteristics should be detailed: peatland, vegetation, surrounding geology and hydrology, proximity to anthropogenic sources, and bog preparation and harvest techniques.

Further information is needed with respect to:

- Definition of relationship between peat chemistry and the chemistry of peat water.

- Definition of impacts of various harvesting operations on water quality, and particularly on receiving waters of different buffering capacities.

- Assessment of potential toxicological effects on waters of runoff from harvest areas.

SOMMAIRE ET RECOMMANDATIONS

La documentation à laquelle on se réfère relativement à la chimie de la tourbe et des eaux de tourbe comprend principalement les résultats d'études menées sur le terrain dans diverses parties du monde. L'accent a été mis sur les données qui pourraient se rapporter à l'utilisation de la tourbe canadienne présentant un potentiel énergétique, de sorte qu'on a tenté autant que possible de se limiter aux données relatives aux latitudes septentrionales et subseptentrionales.

Les paramètres particuliers définis dans la documentation dénotent les intérêts des chercheurs et les différentes utilisations des ressources en tourbe. De nombreuses données portent sur l'utilisation de la tourbe comme matière première dans l'industrie chimique. Cependant, les données tirées de sources traitant de chimie sont issues d'une variété de procédés d'extraction et ne sont applicables, a-t-on estimé, à l'exploitation de la tourbe naturelle. Il existe aussi un vaste ensemble de données sur la chimie de la tourbe et des eaux de tourbe provenant de tourbières exploitées en agriculture et en foresterie qui ont été enrichies d'engrais ou de chaux. En ce qui a trait à certaines caractéristiques de la tourbe et des eaux de tourbe comme leur chimie organique, il s'agit là des seules sources disponibles de sorte que ces données ont été retenues. Cependant dans l'ensemble, les données d'ouvrages en agriculture et en foresterie n'ont pas été incluses.

Voici les sources d'information utilisées dans ce projet: comptes rendus du Congrès international sur la tourbe, résumés sur la tourbe, résumés en agriculture, résumés en biologie, résumés en chimie, Service national d'information technique; Symposium sur la tourbe comme source d'énergie de remplacement, Symposium sur l'évaluation de la gestion de la tourbe comme source d'énergie et publications du Minnesota Peat Program. De cette documentation, on a tiré des références pertinentes. On a identifié dans ces références des publications pour ensuite se les procurer. L'accès à certaines de ces références qui ne sont pas disponibles au Canada a posé quelques problèmes mineurs.

D'autres données, dont la plupart n'étaient pas publiées, ont été obtenues auprès d'employés des gouvernements provinciaux et fédéral et de chercheurs des universités et de l'entreprise privée.

Il existe au Canada peu de données sur la chimie de la tourbe et des eaux de tourbe, notamment en ce qui a trait aux paramètres identifiés dans la liste des produits chimiques toxiques de la Direction générale de la pollution des eaux. Même si les tendances générales notées dans la chimie de la tourbe et des eaux de tourbe sont applicables à l'environnement canadien, il est impossible de prévoir à partir de la documentation la chimie éventuelle propre à un lieu particulier dû à la variabilité des facteurs influant sur la densité.

Comme certaines provinces sont à inventorier leurs ressources en tourbe et qu'on prévoit mettre sur pied dans un avenir rapproché certaines exploitations pilotes de la tourbe comme combustible, le moment est opportun de créer une banque de données, propres à des lieux particuliers, se rapportant à la chimie de la tourbe et des eaux de tourbe au Canada. Il faudrait mettre l'accent sur l'identification des contaminants organiques à l'état de trace. Il faudrait évaluer la teneur en contaminants organiques des eaux extraites de la tourbe brute. D'autres paramètres d'intérêt particulier seraient la concentration des différents métaux lourds présents dans les tourbières. Des échantillons d'eau prélevés dans la tourbe devraient être analysés et plus particulièrement contrôlés dans le temps. Ce souci vient du fait que le taux de décomposition des humates varient en fonction et du temps et du pH. Les polluants éventuels, initialement absorbés par les humates, seront très vraisemblablement entraînés dans les eaux environnantes lorsque les humates se décomposeront.

Dans les programmes visant à déterminer la composition chimique de la tourbe et des eaux de tourbe, il faudrait étudier en détail les caractéristiques suivantes: type de tourbière, végétation, géologie et hydrologie locales, proximité de sources anthropogènes et méthodes de préparation des tourbières et de récolte de la tourbe.

Il faut recueillir de plus amples renseignements sur:

- Définition de la relation entre la chimie de la tourbe et celle des eaux de tourbe.
- Définition des répercussions de différentes opérations de récolte sur la qualité des eaux et, notament, sur des eaux réceptrices de différentes capacités tampons.
- Evaluation des effets toxicologiques potentiels sur les eaux de ruissellement des zones exploitées.

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1.0 INTRODUCTION

As part of the effort to achieving the National Energy program goal of self-sufficiency, the Government of Canada has been assessing the potential energy resources in Canada. Non-traditional sources of energy are being considered in this assessment including renewable energy sources such as solar radiation, and biomass fuel, including peat. The peat reserves in Canada have been described as having significant energy potential (e.g., Tibbetts and Ismail, 1980; House of Commons Canada, 1981).

Peat can be used as a fuel for electric power generation and as a feedstock for liquid and gaseous fuel production. Several feasibility studies of projects using peat as a fuel have recently been conducted although to date there is no large-scale project in Canada using peat as fuel. There is little published information on environmental criteria relating specifically to peat extraction and processing. The environmental implications of developing the peat resource for energy use in Canada are not well understood.

As it is within the mandate of Environment Canada to ensure that developments such as peat mining operations proceed with minimal adverse environmental impacts, the Department has commissioned an assessment of the pollution potential of the peat resource. In this report, information on the chemistry of peat and peat waters and the potential for release of trace contaminants (inorganics, organics and radionuclides) from peat and peat waters has been assembled.

The specific goals were to:

(1) Compile a comprehensive listing of the sources of information on the assessment of the pollution potential of activities pertaining to the peat resource;

(2) Investigate the sources most likely to contain information relevant to the Canadian scene in terms of peat as potential energy sources;

(3) Prepare a list of references containing: qualitative/quantitative data on specific parameters cited in the Water Pollution Control Directorate working list of toxic chemicals; qualitative/quantitative information on environmental impacts of peat harvesting/dewatering; and published or proposed environmental criteria for peat harvesting or dewatering;

(4) Prepare a list of references which contain the information specified above;

(5) Provide an abstract and an interpretation of the data presented;

(6) Identify information gaps in the literature reviewed;

(7) Prepare a survey of the project; and

(8) Identify Canadian peat deposits or areas with the greatest potential to be developed as energy sources and indicate the probability that they will be used for combustion and conversion prior to 1999.

The information required for the project was assembled from computerized literature surveys, discussions with provincial and federal government personnel and representatives from private industry such as consultants and peat producers.

1.1 Peat

Peat is a natural product formed largely as a result of slow decomposition of plant materials (Morita, 1980).

Aerobic, nutrient-poor environments having high moisture content and low pH such as are found in bogs, swamps and muskegs present favourable conditions for the formation of peat. As plant material decomposes (humifies), bulk densities increase and calorific values increase. During this process the organic matter decomposes to form humus. The basic system which has been used to describe the degree of humification of peat is the von Post system which is described in Table 1. Also shown in this Table are dry bulk densities which correspond with levels of humification. Another system of peat classification, advanced by the U.S. Department of Agriculture, (Farnham, 1968) is based on agricultural criteria (contents of fibres larger than 0.1 mm) for organic soils. The types of peat recognized include Fibric which corresponds to H1 - H3 on the von Post scale. This is light peat having a fibre content greater than 67%. Hemic, a dark peat, corresponding to H4 - H6, has a fibre content between 33 and 67%. Sapric peat, H7 - H10, is a black peat with a fibre content of less than 33%.

TABLE 1

von POST CLASSIFICATION SYSTEM[1]

		Mean Dry Bulk Densities (kg/m^3)
H-1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains easily identifiable. No amorphous material present.	45
H-2	Almost completely undecomposed peat which, when squeezed, releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.	60
H-3	Very slightly decomposed peat which, when squeezed, releases brown water, but for which no peat passes between the fingers. Plant remains still identifiable, and no amorphous material present.	75
H-4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains slightly pasty and has lost some of the identifiable features.	90
H-5	Moderately decomposed peat which, when squeezed, releases very "muddy" water with also a very small amount of amorphous granular peat escaping between the fingers. The structure of plant remains is quite indistinct although it is still possible to recognize certain features. The residue is strongly pasty.	105
H-6	Moderately strongly decomposed peat with a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is strongly pasty but shows the plant structure more distinctly than before squeezing.	120
H-7	Strongly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.	135
H-8	Very strongly decomposed peat with a large quantity of amorphous material and very indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.	150
H-9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed, almost all the peat escapes between the fingers as a faintly uniform paste.	165
H-10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.	180

[1] Taken from von Post (1922)

In the Canadian system of Soil Classification, the classification for three types of peat considered (fibric, mesic and humic) are the same as in the U.S. system except that the fibres referred to are larger than 0.15 mm.

The chemistry of the organic matter can vary from an empirical formulation of $C_{1200} H_{813} O_{389} N_5S$ for poorly decomposed peat to $C_{293} H_{409} O_{20} N_5S$ for a well decomposed peat (Morita, 1980).

There is some debate over which types of peat can be used for energy peats. In general, Sphagnum peats with a degree of humification of H4 or greater and sedge peats of H3 or greater can be used as fuel peats. Normally these humification levels occur at or near the bottom of peat deposits below less humified material. Less humified material may be more valuable if used for horticulture (Pyavchenko, 1980).

Bogs and fens are the most common peat deposits. Differentiation of the two types is on the basis of the route by which nutrients reach the vegetation which will ultimately decompose to become peat. Bogs can be described as areas in which there is very little water movement and the input of nutrients is mainly from precipitation. Bogs are termed ombrogenic. Due to their generally nutrient-poor status they may also be termed oligotrophic. Bogs have been described by Zoltai et al. (1974) as:

> Peat-covered areas or peat-filled depressions with a high water table and a surface carpet of mosses (chiefly Sphagnum). The water table is at or near the surface of the bog in spring and slightly below during the

> remainder of the year. The mosses often form hummocks, separated by low wet interstices. The bog surface is often raised, or if flat, level with the surrounding wetlands. It is virtually isolated from mineral soil waters. Hence the surface bog waters and peat are strongly acid and the upper peat layers are extremely deficient in mineral nutrients. Peat is usually found in situ (autochthonous peat) under closed drainage, and oxygen saturation is very low. Although bogs are usually covered with Sphagnum, sedges may grow on them. They may be treed or treeless and they are frequently characterized by a layer of Ericaceous shrubs.

The raised ombrogenic bog is common to New Brunswick, Eastern Quebec, Labrador, Newfoundland, Nova Scotia and Prince Edward Island. The European equivalent is a high-moor bog.

In fens, the influence of groundwater is of paramount importance in the provision of nutrients and the regulation of pH. Fens are termed minerogenic and tend toward being eutrophic. According to Zoltai _et al_. (1974):

> Fens are peatlands characterized by surface layers of poorly to moderately decomposed peat, often with well decomposed peat near the base. They are covered by a dominant component of sedges although grasses and reeds may be associated in local pools. Sphagnum is usually subordinate or absent, with the more exacting mosses being common. Often there is much low to medium height shrub cover and sometimes a sparse layer of trees. The waters and peats are less acid than in bogs of the same area and sometimes show alkaline reactions. Fens usually develop in restricted drainage situations where oxygen saturation is relatively low and mineral supply is restricted. Usually very slow interval drainage occurs through seepage

> down very low gradient slopes, although sheet flow may occur during spring melt or periods of heavy precipitation.

Peatlands which reflect characteristics of both fens and bogs, i.e., having a small contribution of groundwater coupled with precipitation, are termed transitional. In these areas, pH levels are intermediate between those occurring in bogs and fens and the vegetation is characteristically a mixture of types.

Fens are generally wetter than ombrogenic bogs. The European equivalent to a fen would be low-moor. Fens are more common to wet areas of central Canada than in eastern Canada. Peatland terminology is shown in Fig. 1.

1.2 International Fuel Exploitation

A review of the current world-wide peat fuel utilization leads to the conclusion that while peat is used as a fuel source its importance in the global energy scheme is minor.

Use of peat as fuel has been described for various countries (Monenco Ontario Ltd., 1981):

Ireland:	5×10^6 tonnes of fuel peats are used to fire six power plants representing 25% of their energy requirements.

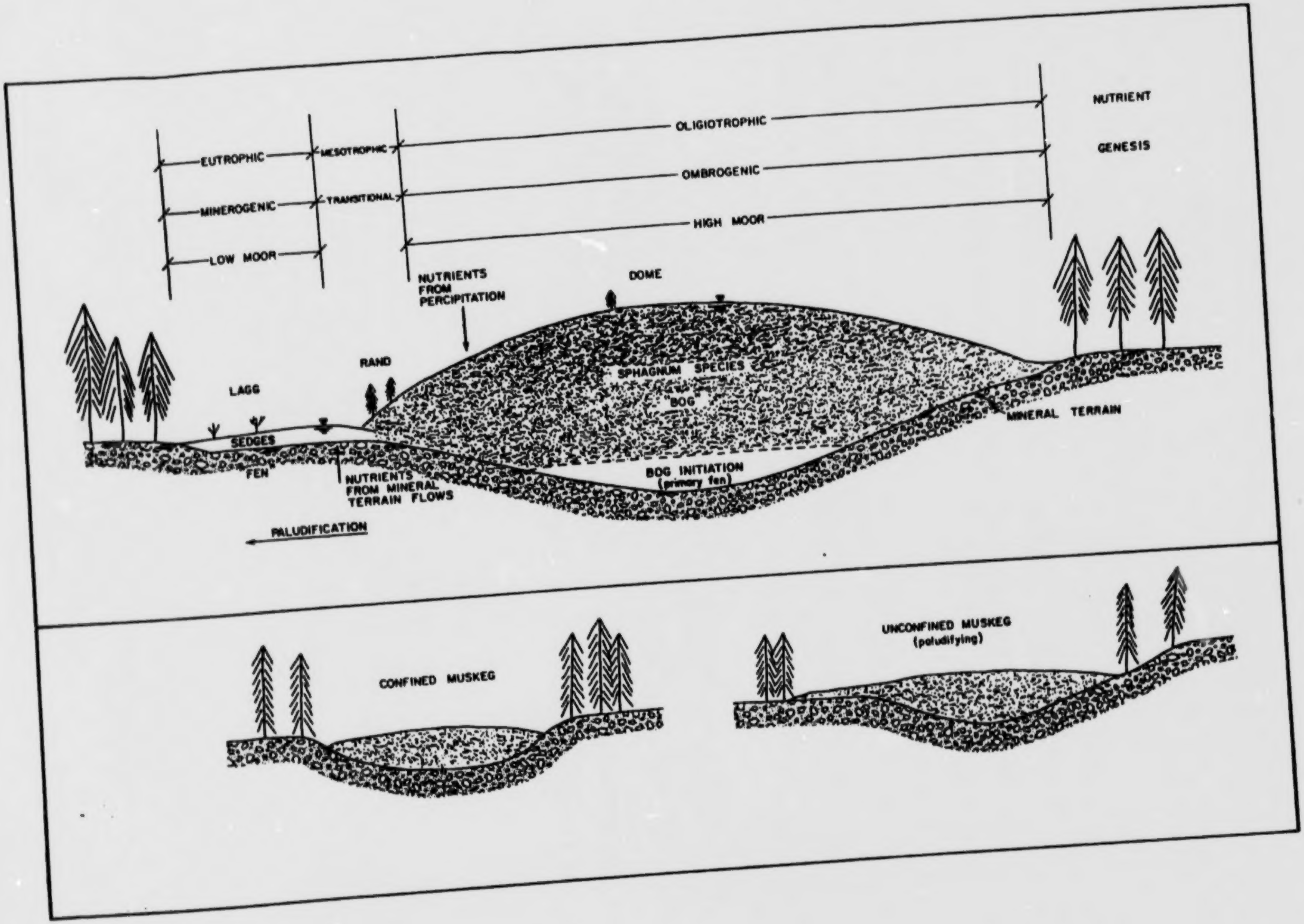
NUTRIENT
GENESIS
EUTROPHIC
MESOTROPHIC
OLIGIOTROPHIC
MINEROGENIC
TRANSITIONAL
OMBROGENIC
LOW MOOR
HIGH MOOR
NUTRIENTS FROM PERCIPITATION
DOME
RAND
LAGG
SPHAGNUM SPECIES
BOG
MINERAL TERRAIN
SEDGES
FEN
NUTRIENTS FROM MINERAL TERRAIN FLOWS
BOG INITIATION (primary fen)
PALUDIFICATION
CONFINED MUSKEG
UNCONFINED MUSKEG (paludifying)

Figure 1. Generalized peatland terminology.

Finland: With a projected reserve of 100-120 x 10^9 m^3 of peat available and a surveyed 24.4 x 10^9 m^3 of fuel peats, Finland utilizes peat fuel for a small amount of its total national energy requirement (Lappalainen, 1980). Only 2% of the national energy needs are served by peat with a projected potential use to 7%.

Sweden: Fuel peat potential is being investigated, however, the peatland resource in Sweden is used principally for horticultural purposes.

Germany: Some of the peat resource has been used as fuel but with a dwindling reserve, the emphasis has shifted to exploitation of the resource for horticultural purposes.

China: This country utilizes 725,000 tonnes of fuel peats and 1.3 x 10^6 tonnes of horticultural peats annually. No estimate of the national energy base is available.

USSR: The Soviet Union uses 100 x 10^6 tonnes of peat which satisfies approximately 2% of its annual energy needs.

Jamaica: The use of peat may be technically and economically feasible, however, peat is viewed as a temporary energy source until such time as the alternatives can be developed. Major factors in this assessment include environmental concerns to do with destruction of valuable wetland habitat (Robinson, 1980).

Although on an international basis peat is used for fuel, it is clear from the literature that this alternate energy source is of only localized importance.

Pyavchenko (1980) has suggested a ban on the use of peat for fuel or other energy-related products. He claims that low-moor peats are more efficiently utilized for agricultural purposes. The Sphagnaceous high-moor peats are of little or no energy use and have limited in situ value for crop production. The high-moor peats, however, can be used as litter or in some cases used in the production of an albuminous food for cattle.

Numerous authors have estimated the total peatland resource in Canada (Tables 2 and 3), however only about 1.3% of the total resource has been properly evaluated (Tibbetts and Fraser, 1978).

Also it may not be feasible to use some of the recognized peat reserves. Although as much as 325,000 km^2 of fuel peats (sedge-type) with an average depth of 1.5 to 2.0 m are indicated as available in the Hudson Bay lowlands (Wickware et al., 1980), this peat resource is not recommended as a potential fuel source due to the economics of mining and transporting as well as the limited working season available.

TABLE 2

PEAT RESOURCES OF CANADA[1]

PROVINCE	POTENTIAL/INFERRED PEAT RESOURCES		MEASURED PEAT RESOURCES		% OF TOTAL PEATLAND AREA
	Hectares	Tonnes[2] x 10^5	Hectares	Tonnes[2] x 10^6	
Newfoundland	2,000,000	3,400	360,000	612	18.0
Nova Scotia	10,000	45	5,100	23	50.0
Prince Edward Island	2,000	2	2,000	2	100.0
New Brunswick	100,000	170	60,000	103	60.0
Quebec	12,000,000	20,680	50,000	64	0.4
Ontario	16,000,000	27,580	62,000	135	0.4
Manitoba	5,500,000	9,525	106,000	103	2.9
Saskatchewan	4,000,000	6,890	16,000	27	0.4
Alberta	10,000,000	17,240	1,600	3	0.2
British Columbia	970,000	1,630	6,000	20	0.6
NWT and Yukon	- NOT AVAILABLE -				
TOTAL	50,582,000	87,162	668,700	1,092	1.3

---

[1] Taken from Tibbetts and Ismail (1980)

[2] At 50% moisture

TABLE 3

WORLD PEAT RESOURCES[1]

	BIOLOGICAL PEATLAND ha x 10^6	PEAT PRODUCTION - TONNES x 10^3		TOTAL
		Fuel Peat	Moss Peat	
Canada	170.0	--	488	488
U.S.S.R.	150.0	80,000	120,000	200,000
U.S.A.	40.0	--	800	800
Indonesia	26.0	--	--	--
Finland	10.0	3,100	500	3,600
Sweden	7.0	--	270	270
China	3.5	800	1,300	2,100
Norway	3.0	1	83	84
Malaysia	2.4	--	--	--
United Kingdom	1.6	50	500	550
Poland	1.4	--	280	280
Ireland	1.2	5,570	380	5,950
West Germany	1.1	250	2,000	2,250
TOTAL	417.2	89,771	126,601	216,372
TOTAL (Approx.)	420.0	90,000	130,000	220,000

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[1] Taken from Kivinen and Pakarinen (1980)

1.3 Peat Mining and Harvesting Methodologies

Before peat mining begins, the land is usually cleared and drained to facilitate peat removal. The information in the following descriptions of methodologies has been developed from articles by Aspinal and Hudak (1980); Fraser (1979); and Monenco Ontario Limited (1981).

The initial step in harvesting peat involves site preparation including perimeter ditching, surface clearing and production field ditching. The goal of the perimeter ditching is to remove existing standing water and to allow accelerated runoff during snow melt and heavy rains. Surface clearing involves removal of trees, stumps and live moss from the bog. Production field ditches (usually 1 m wide and 1 m deep) are constructed to collect surface runoff and to lower the water table adjacent to the ditch. Spacing and length of ditches varies, however as a general rule, ditch spacing of 20 m would be used with 500 m of ditch per ha of the developed bog (Monenco Ontario Limited, 1981). Surface runoff may be further accelerated by grading the production fields so that they slant toward the ditches. Pre-production bog preparation may take three to five years to complete.

There are basically two commercially viable methodologies for harvesting peat -- dry harvesting and wet harvesting. The basic difference between the two is in the degree of drying at the bog site as opposed to at some central collection piace. Dry-harvesting techniques include milled-peat mining, sod peat mining and block cutting. In milled-peat mining, the surface layer of the peat is milled to a depth of from 5 to 50 mm. The layer is left to dry until it has reached approximately 65% moisture at the surface (on a dry weight basis). The layer of peat is then turned over and left to dry until a moisture content of 45-50% is reached. Then the material is harvested either by plowing or by vacuuming. This harvesting technique has the advantage of complete use of the prepared area.

Sod peat mining is based on air drying lumps of peat which have been cut from the bog and mechanically extruded. The sods are left on the surface until approximately 75% moisture content (dry weight) has been reached. Then they are stacked in windrows and left to dry until approximately a 35% moisture content has been achieved.

Block cutting, a mechanized version of the original manual system, involves cutting 30 x 10 x 10 cm high blocks (Monenco Ontario Limited, 1981) which are stacked and allowed to dry in the wind. Utilization is generally limited to approximately 60% of total prepared area. Block cutting is restricted to mining of surficial horticultural peat deposits, but only a small percentage of horticultural peat is mined by this method.

The length of the season for the dry-harvesting methods depends directly on climatic conditions suitable for drying. Due to variations in climate, the dry-harvesting season in Canada may vary from 3-4 months. Any peat required outside this harvesting period must be taken from stockpiles. The average annual yield from dry-harvesting methods in north temperate latitudes is between 100-180 t of fuel peat per ha. Large areas must be developed if harvesting machinery is to be used efficiently.

In wet-mining, the peat is not left to dry on the site but is removed and taken directly to the user or to specialized drying equipment. Wet-mining techniques have certain advantages in that bogs which are difficult to drain can still be mined, the costs of mining may be reduced due to reduced handling, and the length of the harvest season may be increased. The major drawback to the use of wet-mining systems is the need to dewater the peat prior to use. Wet techniques which include slurry ditch, hydropeat and slurry peat methods have been used infrequently (Aspinal and Hudak, 1980). Although wet-mining systems disrupt less land area and are least affected by meteorological factors, wet-mining systems are still considered to be in their developmental stages particularly with respect to dewatering techniques for the production of fuel peat (Carncross, 1980). This is particularly of concern due to the high volumes of water used in wet-harvesting and the colloidal content of fuel peat which complicates mechanical dewatering (Tsaros, 1980). Homogeneity of the peat deposit is preferable when mining by wet techniques is considered. Heterogeneity appears to be more typically the case which may cast further doubt on the overall effectiveness of these methods.

1.4 Moisture Content

Normally peat is evaluated in a similar way to most mineral soils in that moisture is presented based on a dry particulate weight. These values lead to the high percentages commonly noted in the literature pertaining to engineering studies. It is of interest to note that recent studies for fuel peats now utilize the moisture content as a percentage of the wet weight or total weight. The use of a wet weight analysis can be extremely misleading.

The following example is given:

> A wet weight analysis of in situ peat may yield a moisture content of 95%. The same data analysed on a dry weight basis yields a moisture content of 1900% (i.e., each gram of dry solids contains 19 grams of water).
>
> The dry weight moisture content gives a clear and concise impression of the "wetness" of the peat and is the recommended method of reporting.

1.5 Effects of Mining and Harvesting on Water Quantity

The two principal methods of peat harvesting (wet and dry) vary somewhat with respect to their impact on drainage. The preclearing of the bog site which is necessary in both types of harvesting has an initial effect on the hydrology of the bog. In a review of the hydrological factors of peat harvesting, it was suggested that the overall impact of vegetation removal may be an increase in maximum discharge and total water yield from the immediate harvest area (Brooks and Predmore, 1978).

Depending on the kind of drainage systems developed, wet- and dry-harvesting methods may differ significantly in their effects on water yield following pre-development clearing (Okowski and Olesinski, 1976). Undrained peatlands have a water content of 90-95 percent (by volume) (Korchenov *et al*., 1976). The height of the water table in the bog is affected by the intensity of drainage, and determined by both ditch spacing and depth. The water table may be lower when ditches are relatively close together (Ferda and Novak, 1976). Factors related to subsidence of the peat, which is due in part to lowering the water table, result in changes to the physical and hydraulic properties of peat which lead to increases in bulk density of the surface layer.

If surface peat is dried to below 30% moisture content on a dry weight basis, the peat exhibits a granular surface with hydrophobic characteristics (Olkowski and Olesinski, 1976). Reduced infiltration and increased surface runoff results (Tallis, 1973).

Lowering of the water table also would result in decreases in evapotranspiration. A survey of drainage impact on peatlands indicated decreased spring discharges and increased summer, fall and winter discharges. The total discharge generally increased (Brooks and Predmore, 1978). The authors indicated, however, that due to absence of specific data in these studies pertaining to drainage intensity, size of drained areas, and watersheds, specific conclusions could not be drawn. Wet harvesting may increase maximum discharge from the harvest site and there may be a decrease in minimum discharge (Brooks and Predmore, ibid.)

The effect of peat mining on the hydrology of peatlands is not clearly understood. There are two prevailing theories with respect to runoff following storm events. One theory suggests that surface runoff and peak discharge would increase, while the other suggests that runoff would be delayed and peaks smoothed. More research must be conducted in order to develop a better understanding of mining impacts on hydrology.

2.0 PEAT CHEMISTRY

The chemical composition of wetland plants, and ultimately of peat, is highly varied. No average composition for an individual species or ecological grouping of species would be reliable (Boyd, 1978). Based on the review of the literature of peat chemistry, major factors which influence the concentration of inorganic chemical substances in peat include: nature of peatland, source of chemical substances, proximity to anthropogenic sources, and degree of humification.

A number of investigations have been conducted to measure the contribution of trace elements from the atmosphere to peat vegetation. Levels of lead and cadmium (Sapek, 1976), tritium (Gorham and Hofstetter, 1971) and arsenic (Arafat and Glooschenko, in press) were reported which were attributed to atmospheric fallout. Levels of lead and cadmium were highest in surface layers of organic soils. The concentration of lead in the upper horizon was 10.60 ppm while cadmium was 0.15-1.60 ppm (Sapek, 1976). Six of 14 bogs investigated contained uranium in amounts above 30 ppm in ash. Tritium in surface bog peats exists in concentrations similar to that in atmospheric precipitation. Most of tritium is apparently removed rapidly by evapotranspiration or by lateral runoff, however, there is a small accumulation of tritium at the zone between less humified and well humified materials (Gorham and Hofstetter, 1971). An increase in arsenic concentration was found in bog vegetation near smelters (Arafat and Glooschenko, in press). The concentrations decrease with distance from the smelters. Levels found near the smelters were at least 20 times the background concentration of arsenic found in more remote locations (Arafat and Glooschenko, ibid.).

Levels of metals in bog vegetation have been related to atmospheric fallout by various authors including Crisp, 1966; Pakarinen and Tolonen, 1976; Damman, 1978; Glooschenko and Capobianco, 1978; Furr _et_ _al_., 1979; Livett _et_ _al_., 1979; and Pakarinen _et_ _al_., 1980. Anthropogenic sources were implicated in elevated concentrations of lead, copper, nickel, chromium, iron and zinc. Such sources were also implicated in elevated levels of barium, molybdenum, titanium and vanadium (Furr _et_ _al_., 1979). The increased levels attributed to atmosphere loadings were most prevalent in the surface living layers of the peat and generally decreased with depth. The zone of water level fluctuation has been reported to show elevated concentrations of lead, iron, aluminum and zinc (Damman, 1978; Pakarinen _et_ _al_., 1980).

Chemistry of fen peats is related closely to the geology of the surrounding area while that of bog peats is less so. Analysis of trace metals in a northern Ontario peat bog revealed levels of zinc, lead, copper, chromium, cadmium, and mercury in the low ppm range (Glooschenko and Capobianco, 1982). These values did not vary significantly in terms of peatland type or depth except for lead which was significantly higher in surface peats and fens.

Both vertical and horizontal variation in chemical composition of peats was described by Stewart and Robertson (1968). This variation was attributed to the degree of decomposition, the diversity of specific plant groupings and the proximity of the underlying mineral soil.

Analysis of peat profiles in a British bog indicated that aluminum concentrations were highest in the lower layers of peat and lowest in the upper layers (Chapman, 1964). The fluctuation in levels was attributed to changes in rate of peat formation through the life of the bog (Chapman, ibid.). Iron also was higher in the basal peats than in surface layers.

Levels of 13 elements (aluminum, cobalt, chromium, copper, iron, manganese, molybdenum, nickel, lead, strontium, tin, uranium, and zinc) were analysed from two peat profiles from Finland (Silanpää, 1972). Although there were concentration differences between elements, the general vertical distribution of the elements was similar, with a notable concentration on the surface horizon, a decrease to a minimum in mid-profile, followed by a strong increase in the peat-mineral soil transition zone. This pattern was most apparent for zinc, lead, manganese, strontium, and tin. The author attributes the distribution characteristics to element-lifting properties of plants. Urvas et al. (1979) found a decrease in the levels of exchangeable potassium and soluble phosphorous with depth while calcium increased with depth. Vertical distribution of lead in an ombrogenic Sphagnum bog in Finland was attributed to variations in annual deposition of atmospheric lead rather than vertical movement through the peat profile (Pakarinen and Tolonen, 1977). Manganese, lead, and iron concentrations varied according to plant species in Sphagnum layers of bogs in Finland (Pakarinen, 1978). In vertical profiles lead, zinc, and iron concentrations increased with depth.

The presence of metallic elements in peat samples has been used as a method of identifying the presence of ore bodies. The concentration of rare elements (Kochenov and Kreshtapova, 1967) and microelements (Largin et al., 1972) has been described for peats in the Soviet Union. In general the concentration of these elements reflected the concentration of the surrounding bedrock. Other factors such as pH, peat type, and bog type also affected concentrations. Similar results were reported by Ayräs (1979) from analysis of peats in Finland. Elevated levels of copper have been reported from a bog in southeastern New Brunswick where the source of the copper is apparently a nearby copper ore body (Fraser, 1961). The metal is organically combined as a chelate.

The mechanism by which trace elements form complexes with humic and fluvic acids have been investigated by a number of authors (Kovalev and Generalova, 1967; Lakatos et al., 1972; Andrzejewski and Rosikiewicz, 1975; Sapek, 1975; Bunzl et al., 1976; Sapek and Zebrowski, 1976; and Schnitzer and Kerndorff, 1981). Metals form complex chelate bonds of considerable ionic character (Lakatos et al., 1972). Peat has been shown to absorb metals in the following sequence of rates: lead > copper > cadmium > zinc > calcium > . Lead is bound by peat strongly and the rate of release due to desorption is low. The desorption of both cadmium and zinc can be rapid (Bunzl et al., 1976).

Peats consist of plant fibres and polyelectrolyte humic material. The polyelectrolyte, ion exchange and metal ion chelation properties of humic materials are considered to make a significant contribution to the surface adsorption properties of peats. H-bonding and π-bond complexing by the aromatic rings may also contribute to the sorption properties of peats (Anonymous, 1972).

Borowiec and Baron (1976) have reported decreases in the concentrations of boron, manganese, lead, chromium, molybdenum, vanadium, copper, zinc, nickel, strontium and calcium in peat as the acidity of the surrounding habitat increased. This was attributed to increased acidity effects on the mobility of the microcomponents and the resultant decreased concentrations in the soil. A high correlation was found between the soluble mineral and peat fibre contents in an assessment of peats from Minnesota (Brown and Farnham, 1976).

Concentrations of inorganic chemical substances in peat are shown to vary according to vegetation type, bog type, depth in bog, location in bog, degree of decomposition, bedrock geology and anthropogenic inputs.

Results of chemical analyses of peat reported for various locations in the world are shown in Tables 4 a and b. It must be borne in mind that peats from cultivated lands may have different chemistry due to addition of fertilizer or neutralizing agents.

TABLE 4a

CHEMICAL ANALYSES OF PEAT

REPORTED FOR VARIOUS LOCATIONS IN THE WORLD

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	pH	UNITS	% C	Mg	Na	Ca
Finland (virgin bog)	Sillanpää 1972	sphagnum - - - - - bog		- - - - 270 cm	4.0 - 5.0	mg/kg				
Finland (virgin bog)	Sillanpää 1972	sphagnum - - - - - bog		- - - - 185 cm	4.0 - 5.0	mg/kg				
Southeast Finland 62° 10' 24"	Erämetsä et al., 1969	- - - - - bog		8 - - - - 0-6 m	4 - 6.5	mg/kg				
Phytaa Munasuo S. Finland (coastal) 60° 34' N	Pakarinen et al., 1980	sphagnum - - - - - bog	- - - - - June 1977	- - - - 0-50 cm	<4	mg/kg				
Janakkala Suurisuo S. Finland (inland) 60° 59' N	Pakarinen et al., 1980	sphagnum - - - - - bog	- - - - - Oct. 1977	- - - - 0-90 cm	<4	mg/kg				
Holland Marsh Ont., Canada (cultivated)	Mathur and Sanderson 1980	- - - - - marsh. cult. for vegs.	- - - - - Nov. 1977	24 fields - - - - 0-15 cm	5.4 (5.0 - 5.75)	mg/kg	44.12 (40.1 - 46.2)	% 0.227 (0.06 - 0.34)		% 3.12 (2.00 - 4.08)
Keswick Marsh Ont., Canada (cultivated)	Mathur and Sanderson 1980	- - - - - marsh. cult. for vegs.	- - - - - Nov. 1977	6 fields - - - - 0-15 cm	5.57 (5.2 - 6.1)	mg/kg	44.49 (41.6 - 50.4)	% 0.227 (0.18 - 0.32)		% 2.71 (1.88 - 3.75)
North of Sudbury, Ont. 12 bogs	Glooschenko et al. unpublished paper	sphagnum moss - - - - - bog	- - - - - early Sept. 1978			mg/kg				
Farnham Quebec (partially drained)	Levesque et al., 1980	mesic humisol - - - - - fen		5 - - - - 0-120+		mg/kg	29.43 - 31.82	127 - 257		mg/g 2.0 - 6.0
Ormstown Quebec (partially drained)	Levesque et al., 1980	humic mesisol - - - - - bog		6 - - - - 0-160 cm		mg/kg	25.49 - 33.37	310 - 650		mg/g 6.3 - 15.0
Clair (St. Charles) Quebec (partially drained)	Levesque et al., 1980	fibric mesisol - - - - - bog		7 - - - - 0-165		mg/kg	26.60 - 30.69	275 - 410		mg/g 1.0 - 1.3
St. Chrysostome Quebec (little drainage)	Levesque et al., 1980	humic mesisol - - - - - mesic swamp		5 - - - - 0-150		mg/kg	28.90 - 33.25	650 - 3300		mg/g 5.3 - 15.0

[a] The first number given is the mean except where only the range (two numbers separated by a dash) was available. A single number in brackets is the standard deviation except where only the standard error (indicated by an asterisk beside the location name) was available.

Cl	Cu	Zn	Pb	Cr	Cd	Hg	As	P	Mn	Al	Ba	Mo	Se
	<1 -[a] 90	7 - 100	2 - 40	2 - 140					10 - 650	% <0.05 - 9.0		<0.1 - 4.6	
	2 - 70	<5 - 65	<2 - 30	2 - 130					10 - 650	% <0.05 - 6.0		<0.1 - 5	
			<10 - 75										
	1 - 7.25	28 - 100	18 - 38	-					<30 - 150				
	1 - 10	20 - 56.25							<30 - 125				
	234.5 (70 - 500)	34.38 (20 - 70)	27.12 (16 - 50)						204.4 (125 - 550)				
	60.92 (15.5 - 95.0)	80.83 - (50.0 - 125.0)	37.83 (17.0 - 77.5)					(100.0 - 250.0)	164.6 (1000 - 2500)				
	16 (4 - 124)	34 (21 - 57)	27 (15 - 78)	18 (8 - 35)	1.8 (1.0 - 2.9)								
	7.5	5.7 - 42.7	1.2 - 27.5	10 - 10	1.0 - 2.0			145 - 605	6.0 - 30.0	947 - 3225			0.58 - 0.81
	2.5 - 10.0	6.5 - 120.0	3.7 - 82.5	5.0 - 12.5	0.5 - 1.5			180 - 422	2.5 - 22.5	752 - 1812			0.41 - 0.67
	2.5 - 3.2	18.0 - 54.7	1.2 - 2.5	7.5 - 7.5	1.0 - 1.9			95 - 175	3.7 - 20.0	325 - 632			0.22 - 0.37
	3.7 - 6.5	6.7 - 16.0	1.7 - 8.0	7.5 - 7.5	<0.3 - 1.7			107 - 325	3.7 - 120.0	450 - 787			0.33 - 0.65

Ba	Mo	Se	Co	K	Si	Ni	Sn	Sr	V	U	Ti	B	Fe
	<0.1 - 4.6		0.2 - 30.0			1.3 - 40	<0.1 - 2	5 - 240	<1 - 200				% 0.05 - 5
	<0.1 - 5		0.25 - 20.0			1.9 - 45	<0.1 - 2	6 - 325	<1 - 170				% 0.05 - 5
						10 - 75				<30 - 200			
													265 - 1000
													250 - 750
				% 0.279 (0.20 - 0.45)		4.19 (1.0 - 7.0)							% 0.750 (0.5 - 1.35)
				0.257 (0.16 - 0.43)		5.53 (4.0 - 9.3)							% 0.842 (0.65 - 1.11)
						nd 59							
		0.58 - 0.81	5.0 - 7.5	10.0 - 60.0		<2.0		25.0 - 70.0			<3.0		775 - 3062
		0.41 - 0.67	2.5 - 2.5	9 - 150		1.5 - 3.5		15.0 - 40.0			<3.0		305 - 3050
		0.22 - 0.37	2.5 - 2.5	17.5 - 20.0		<2.0		10.0 - 25.0			<3.0		300 - 605
		0.33 - 0.65	2.5 - 7.5	12.5 - 32.5		<2.0 - 5.5		20.0 - 147.5			<3.0		675 - 1525

TABLE 4a (CONT'D)

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	pH	UNITS	% C	Mg	Na	Ca
Keswick Ontario (partially drained)	Levesque et al., 1980	typic mesisol - - - - - marsh		4 - - - - 0-160		mg/kg	23.12 - 29.69	727 - 1630		mg/g 7.5 - 13.3
Southern Finland * 6 bogs	Pakarinen 1978	(hummock) sphagnum - - - - - bog	- - - - - Oct. 1976	- - - - 0-7 cm		mg/kg				
Southern Finland * 6 bogs	Pakarinen 1978	(hollow) sphagnum - - - - - bog	- - - - - Oct. 1976	- - - - 3.1 cm		mg/kg				
Northwest to Centralwest Finland 15 bogs	Pakarinen and Tolonen 1976	sphagnum - - - - -	- - - - - Sept. 1974	5 per bog - - - - 3.5 cm		mg/kg				
Southwest of Great Slave Lake, N.W.T. 60° 50' N, 116° 40' W West of Edmonton, Alta. 53° 30' N, 114° W	Pakarinen and Tolonen 1976	sphagnum - - - - -	- - - - - June 1973	5 per bog - - - -		mg/kg				
South Finland 60-62°N	Pakarinen and Tolonen 1976b	sphagnum - - - - - raised bog	- - - - - Sept. - Oct. 1975	7 bogs 5 samples/ bog 35 - - - - 40 cm		mg/kg				
Sweden 57° 40' N, 13° 40' E	Pakarinen and Tolonen 1976b	sphagnum - - - - - raised bog	- - - - - 1969	2 sites - - - -		mg/kg				
West Germany 53° 40' N, 9° 15' E	Pakarinen and Tolonen 1976b	sphagnum - - - - - raised bog	- - - - - 1969	2 sites - - - -		mg/kg				
Kuwasy bog Northeast Poland (reclaimed)	Sapek, 1974	strongly decomposed alder peat - - - - - bog		2 profiles - - - - 100 cm		mg/kg				
Southern Central Finland 61° 41' N, 24° 06' E	Raikamo (1977) as cited by Tolonen et al., 1979	- - - - - whole mire	- - - - - October, May, July, September	61 - - - - 25-500 cm	4.16	mg/kg		489		2821
Southern Finland	Pakarinen 1981	sphagnum - - - - - ombrotrophic raised bogs		4 bogs 3-6 samples/ bog - - - - 80-420 cm		mg/g		0.46 (0.35 - 0.64)		1.14 (0.63 - 1.90)
Hannukainen area Poland	Ayräs 1979			93 - - - -		mg/kg				

Cl	Cu	Zn	Pb	Cr	Cd	Hg	As	P	Mn	Al	Ba	Mo	Se
	2.5 - 4.0	8.5 - 15.2	2.0 - 3.2	7.5 - 7.5	<0.3			155 - 397	50 - 150	452 - 662			0.4 0.6
	6.1 (0.6)	37.3 (3.2)	23.9 (2.9)						176 (38)				
	5.1 (0.4)	33.4 (3.6)	18.5 (1.5)						33 (3)				
	6.3 (3.8 - 22.2)	34 (24 - 48)	5.6 (2.5 - 9.1)	5.0 (2.0 - 7.8)	0.3 (0.17 - 0.47)	0.037 (0.010 - 0.085)			169 (32 - 253)			0.49 (0.13 - 2.31)	
	2.8 - 3.2	79 - 180	0.7 - 7.3	0.5 - 2.4	0.17 - 0.20	0.029 - 0.085			51 - 77				
	4.5	47	19	1.6					99				
	10.6 - 14.3	190 - 218	56 - 78	2.8 - 3.7					70 - 114				
	9.3 - 9.4	120 - 184	81 - 81	2.5 - 2.8					49 - 65				
	2 - 10.5	9 - 90	3 - 40						100 - 910				
	8.7	23							27				
	0.0013 (0.0006 - 0.0025)	0.0085 (0.0052 - 0.0118)	0.006 (0.0038 - 0.0083)					0.16 (0.14 - 0.19)	0.0057 (0.0026 - 0.0085)				
	7.7 (6.6)	5.2 (7.4)	5.9 (4.7)									0.660 (0.913)	

Ba	Mo	Se	Co	K	Si	Ni	Sn	Sr	V	U	Ti	B	Fe
		0.47 - 0.61	5.0 - 7.5	7.5 - 50.0		<2.0		32.5 - 72.5			<3.0		3875 - 7300
													586 (74)
													449 (63)
	0.49 (0.13 - 2.31)					1.2 (0.6 - 2.2)							231 (113 - 368)
						(0.2 - 0.8)							82 - 546
						3.4							319
						2.1 - 2.3							360 - 1150
						1.7 - 1.9							350 - 780
			0.25 - 2.6			2.4 - 10							% 3 - 6
				82									2940
				0.10 (0.07 - 0.13)									0.38 (0.16 - 0.69)
	0.660 (0.913)		2.6 (5.1)			4.2 (4.6)							% 0.59 (1.02)

TABLE 4a (CONT'D)

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	pH	UNITS	% C	Mg	Na	Ca
Kinoje Lake Northern Ontario 51° 34' N, 80° 48' W	Glooschenko and Capobianco 1982	- - - - - bog, fen and swamp	- - - - - summer 1976	12 - 69 - - - - 0-40 cm		mg/kg				
Finland	Urvas et al. 1979	carex dominated - - - - - predominantly fen		382-411 - - - - 0-60 cm	4.70 - 4.80	mg/l				579 - 756
Finland	Urvas et al. 1979	sphagnum dominated - - - - - predominantly bog		402-424 - - - - 0-60 cm	4.01 - 4.24	mg/l				233 - 331
Grassington Moor England	Raistrick 1953 as cited by Livett et al., 1979	Eriophorus vaginatum - - - - - bog		- - - - 30 cm		mg/kg				
Finland	Pakarinen and Tolonen 1972			- - - - 0-105 cm		mg/kg				
Kinoje Lake area Northern Ontario 51° 34' N, 80° 48' W	Glooschenko and Capobianco 1978	sphagnum - - - - - bog	- - - - - summer 1976	6 sites 9 samples - - - - top 10 cm and some dead parts		mg/kg		530 (167)		1860 (405)
Porter Lake Caribou Range N.W.T. 67° 42' N, 108° 00' W	Glooschenko and Capobianco 1978	sphagnum - - - - - bog	- - - - - summer 1976	4 samples - - - - top 10 cm and some dead parts		mg/kg		1444 (765)		2224 (500)
S.E. of Yukon Territory in vicinity of Watson Lake townsite	Walmsley and Larkulich 1975	terric-fibric mesisol to typic humisol - - - - - fen		6 sites - - - - surface horizon 0-80 cm	4.1 - 7.2	me/100g		0.8 - 11.3	0.0 - 1.9	8.7 - 94.0
Jedlanka Lublin, Poland	Borowiec and Baran 1976	sedge peat - - - - - fen		3 - - - - 0-55 cm	3.2	mg/kg				
Kinoje Lake area Northern Ontario 51° 34' N 108° 00' W	Glooschenko et al. unpublished manuscript	- - - - - bog		3 sites - - - - 0-40 cm	3.0 - 3.3	mg/kg		% .05 - .10		% .17 - .76
Kinoje Lake area Northern Ontario 51° 34' N 108° 00' W	Glooschenko et al. unpublished manuscript	- - - - - fen		1 site - - - - 0-20	5.8	mg/kg		.10		% 1.64
Traneröds Mosse Southern Sweden 56° 05' N, 13° 10' E	Damman 1978	sphagnum - - - - - bog	80 ha - - - - - fall 1974	- - - - 0-400 cm		mg/g		0.40 - 1.4	0.12 - 0.6	0.4 - 1.7

Cl	Cu	Zn	Pb	Cr	Cd	Hg	As	P	Mn	Al	Ba	Mo	Se
	7 (5)	31 (17)	16 (7)	3 (2)	1 (1)	0.06 (0.03)							
								0.8 - 2.8					
								1.8 - 4.0					
	5 - 52	25 - 211	60 - 800										
			22 - 120										
	14 (0.7)	37 (3)	23 (4)	3.5 (0.8)	1.0 (0.7)	61 (31)			290 (99)				
	13 (1)	45 (12)	7.1 (1.6)	2.8 (0.7)	0.3 (0.2)	83 (19)			273 (125)				
	7.1 - 7.75	24.3 - 77.8	1.7 - 16.9	2.6 - 9.6					31 - 117		23.0 - 211.5	0.16	
	1.30 - 2.68	14.38 - 39.08	3.0 - 22.4						18 - 157.4				
	2.70	29.06	18.5						108.4				
		<0.1 - 3.4											

Ba	Mo	Se	Co	K	Si	Ni	Sn	Sr	V	U	Ti	B	Fe
				13 - 37									
				13 - 32									
													269 (61)
													1002 (1258)
				0.1 - 0.7									
23.0 - 211.5	0.16					1.3 - 3.1		6.1 - 15.8	0.7 - 1.9			2.3 - 6.7	
				% .03 - .08									547 - 1632
				% .01									15262
				<0.02 - 0.18	<0.02 - 0.29					0.22 - 0.82	<0.02 - 0.16	<0.2 - 1.5	0.2 - 3.5

TABLE 4b

CHEMICAL ANALYSES OF PEAT - MINOR ELEMENTS

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	UNITS	Ge	Be	Ga	Zr	Y	La	Cu
USSR	Largin *et al.* 1972	peat - - - - - fen		- - - - genetic horizon	mg/kg		0.2	1.0	8.7	2.5	5.6	12.0
USSR	Largin *et al.* 1972	peat - - - - - bog		- - - - genetic horizon	mg/kg		4.5	0.2	1.8	14.9	8.5	4.5
USSR	Largin *et al.* 1972	peat - - - - - bog		- - - - genetic horizon	mg/kg		1.1	4.5	36.8	11.0	1.7	6.0
In and beyond the Central Urals	Tarakanova 1968	- - - - - bog	20,000 - 48,000 ha and more - - - - -	357 samples from 29 deposits - - - - 0.5 m intervals	mg/kg	0.1	0.05 - 3.7	0.09 - 4.5	0.3 - 7.6	0.02 - 5.9		0.7 - 19
Sackville, N.B. northern	Boyle 1977	*Pohlia nutans* moss - - - - - cupiferous bog		4 samples - - - -	mg/kg	<10	3	6	70	65	142	% 5.6
Sackville, N.B. southern	Boyle 1977	*Pohlia nutans* moss - - - - - cupiferous bog		4 samples - - - -	mg/kg	<10	6	<25	100	83	88	% 2.8

Zn	Pb	Cr	Cd	Hg	As	Mn	Ba	Mo	Co	Ni	B	V	Sb	Ag	W
	0.6	6.2						0.5	3.7	54.6		19.8			
	0.5	2.0						0.3	0.8	1.8		11.0			
	3.9	8.4						0.2	0.3	6.8		1.0			
	0.5 - 42	0.08 - 3.1				123 - 417		0.4 - 2.4	0.5 - 10	0.4 - 49		0.3 - 45			
2.16	34	32	2	0.32	5	4320	3920	1	11	17	<10	46		4.5	<1
196	73	26.8	1.5	0.19	8	2275	3380	2.5	7	37	13	16	2.5	4	

V	Sb	Ag	W	Sn	Tl	Tn	Sr	Sc	Nd	Yb	Ti	P	U	Au
19.8														
11.0														
1.0														
0.3 - 45											53 - 884	1.4 - 169		
46		4.5	<1	1	1.5	<1	55	9	66	15		3000	4.4	2.3
16	2.5	4		1.5	1.5		88	9.6	31	15		1625	140	0.33

2.1 Metals in Peat Ash

Samples of peat ash from New Brunswick (Keys, personal communication, 1982); Ontario (Glooschenko and Capobianco, 1982); Prince Edward Island (R. Bruce Graham Assoc. Ltd., 1974); and Finland (Yliruokanen, 1976) were analysed for heavy metals. Levels of heavy metals in these samples were sufficiently high to suggest that there is potential for pollution from ash produced during the burning of peat for fuel. Concentrations of metals reported in Canadian peats (Glooschenko and Capobianco, 1982) were comparable to levels of metals from U.S. coals and other peats (Cassagrande and Erchull, 1976). These results suggest that combustion of peats may contribute metals to the atmosphere.

Bysiek *et al*. (1972) assessed the combustion of peat as a source of atmospheric mercury and cesium^{137} in Finland. Combustion of peat in Finland was estimated to contribute 12.7 kg of mercury per ha which was considered negligible as compared to amounts produced by other fuels. (This was due mainly to the relative amounts combusted, as mercury concentrations per kilocalorie were similar in peat and coal.) Increased levels of mercury were found immediately adjacent a peat-fired thermal plant. Contribution of cesium^{137} to the environment due to peat combustion was shown to be negligible.

Results of analyses of peat ash are shown in Table 5.

In assessing the potential for release of inorganic contaminants to the environment during peat harvesting operations, the vertical profile of the inorganic contaminant concentrations must be considered. In

LOCATION	REFERENCE	BOG TYPE - - - - - NO. OF SAMPLES	DEPTH OF SAMPLE - - - - - SAMPLING PERIOD	% C	Mg	Na	Fe	Cl	Cu
Prince Edward Island	R. Bruce Graham and Assoc. Ltd. 1974	ombrotrophic bog - - - - - 63							0.9 -[a] 397
New Brunswick	Dave Keys pers. comm. 1982			49.9 (5.14)	4.22 (2.52)	1.34 (1.09)	8.85 (4.92)	195.23 (219.3)	164.5 (321.1)
South and East Finland, 1974 Western Finland, 1975	Yliruokanan 1976	ombrotrophic bog - - - - - 2000	100 cm intervals to bottom of bog - - - - -						210

[a] The first number giv
(two numbers separat
brackets is the stan
are in ppm.

TABLE 5

ANALYSES OF PEAT ASH

Zn	Pb	P	Mn	Al	Mo	K	B	SiO_2	U_3O_8
0.3 - 232	0.2 - 90		0.4 - 232						-0.08 - 27.35
740.5 1083.8)	250.4 (398.4)	0.895 (0.550)	0.205 (0.232)	4.97 (2.83)	0.01 (0.00)	1.06 (1.53)	0.092 (0.105)		1.59 (2.37)
180	250							160	<50

is the mean except where only the range
by a dash) was available. The number in
rd deviation. Concentrations of elements

mining operations for fuel peat, the living material and the less humified surface peats are either stockpiled or used for horticultural purposes. In either case it is unlikely that the inorganic constituents which are present, often in elevated concentrations, would be released on the bog, as it is not likely that the material will rapidly decompose.

The well-humified material, which during harvesting may be exposed to increased oxygen levels and subsequent increased rates of decomposition, may contain lower levels of inorganic chemical substances. Estimates must be developed of the concentrations and release rates of elements in those layers of the bogs which will be exposed during mining operations.

2.2 Organic Chemistry of Peat

Most of the work presented in the literature describes the levels and chemical identification of organic substances naturally occurring within peatlands. The types of materials normally found in peat have been characterized as follows: hemicellulose; cellulose; polysaccharides; lignins; humates; and bitumens. Hemicelluloses, celluloses, polysaccharides decompose to yield bitumens and humates. The relative occurrence of these compounds obtained from a Russian study of fens (low-moors) and bogs (high-moors) indicates that the concentrations of bitumens, lignins and humates increase with decomposition at the expense of the hemicellulose and cellulose (Table 6).

TABLE 6

COMPOSITION OF SOVIET PEATS[1]

	HIGH-MOOR	TRANSITION	LOW-MOOR[2]
Bitumens	7.0 ± 3.25	6.6 ± 2.54	4.2 ± 1.96
Water-soluble and easily hydrolyzed	35.8 ± 12.36	23.9 ± 9.06	25.2 ± 6.10
Reducing substances[3]	13.6 ± 4.48	13.9 ± 5.92	21.6 ±10.54
Humic acid	24.7 ± 10.54	37.8 ± 8.62	40.0 ± 5.99
Fulvic acid	16.6 ± 2.81	15.7 ± 4.06	15.5 ± 3.80
Cellulose	7.3 ± 3.76	3.6 ± 2.46	2.4 ± 1.44
Lignin	7.4 ± 2.88	11.4 ± 3.68	12.3 ± 3.83
Ash	2.4 ± 1.30	4.7 ± 2.56	7.6 ± 3.18

[1] Taken from Clausen and Brooks (1980). All data are given as percent of the dry organic material except ash, which is based on total dry peat.

[2] Low-moor peatlands (fens) are considered to be highly decomposed relative to high-moor bogs.

[3] These substances are part of the "water-soluble and easily hydrolyzable materials." They are reported as percent of the dry organic material in peat. They consist principally of peat hemicelluloses.

Based on the relative percentages of organics reported by Morita (1980) and the quantitative description of raw peat samples (Morita, 1973), the following Table may be derived.

TABLE 7

CONCENTRATIONS OF ORGANICS IN WET PEAT
(mg/cc, wet peat)[1]

	YEARS AFTER CULTIVATION		
	0	3	5
Bitumen	3.5	3.7	3.8
Hemicellulose	11.6	10.3	9.7
Acid-soluble nonhemicellulosics	11.3	11.3	11.5
Cellulose	7.7	6.6	5.8
Acid-soluble noncellulosics	2.0	2.3	2.2
Lignin-humic complex	23.8	25.7	26.9

[1] According to Morita (1980), the phenolic acids and other derivations arise from all of these groups of compounds except the bitumens. Bulk density of sample was 0.22 g/cc, moisture content at a depth of 20 cm was 232%.

2.2.1 Bitumens

Bitumens are comprised of waxes, paraffins (mainly C_{18} - C_{24} hydrocarbons), steroids, terpenes, fats, fatty acids, vegetable oils and free fatty acids. The percent composition of these substances is widely discussed in the literature. However, the percent wax content of a specific peat sample will vary with the choice of extraction solvent as shown in Table 8.

TABLE 8

WAX CONTENT (%) IN PEAT BITUMENS OBTAINED WITH DIFFERENT EXTRACTION SOLVENTS[1]

	WAX (10%)
Petroleum ether	87.0
Gasoline	71.0
Benzene	66.0
Ether	52.0
Acetone	38.0
Methanol	34.0'
n-Butanol	32.0

[1] Taken from Fuchsman (1980)

From bitumen extracts, trace amounts (Table 9) of polycyclic aromatic hydrocarbons (paraffins) have been isolated and identified (Fig. 2).

TABLE 9

CONCENTRATION IN ppb OF POLYCYCLIC HYDROCARBONS IN PEAT. PEAT-PROFILE "GROBES MOOR" NEAR NEUDORF-PLATENDORF[1]

SUBSTANCE	DEPTH OF PEAT 0-20 cm	15-45 cm	55-130 cm	150-170 cm	180-200 cm
Benzo(b,k,j)fluoronthen	14.3	34.9	30.4	39.8	57.8
Benzo(e)pyren	4.3	22.0	20.3	236	22.7
Benzo(o)pyren	0.7	6.2	10.2	78.9	273
Perylen	6.8	8.5	4.0	29.0	3537
Indenol(1,2,3-c,d)pyren	3.8	7.9	8.4	22.7	29.6
Dibenz(a,h)onthrocen	7.1	22.5	6.4	22.2	266
Dibenz(a,c)onthrocen	6.2	13.3	9.9	38.1	128.8
Benzo(ghi)perylen	5.7	33.3	15.1	39.2	105.9

---

[1] Taken from Ellwart (1976)

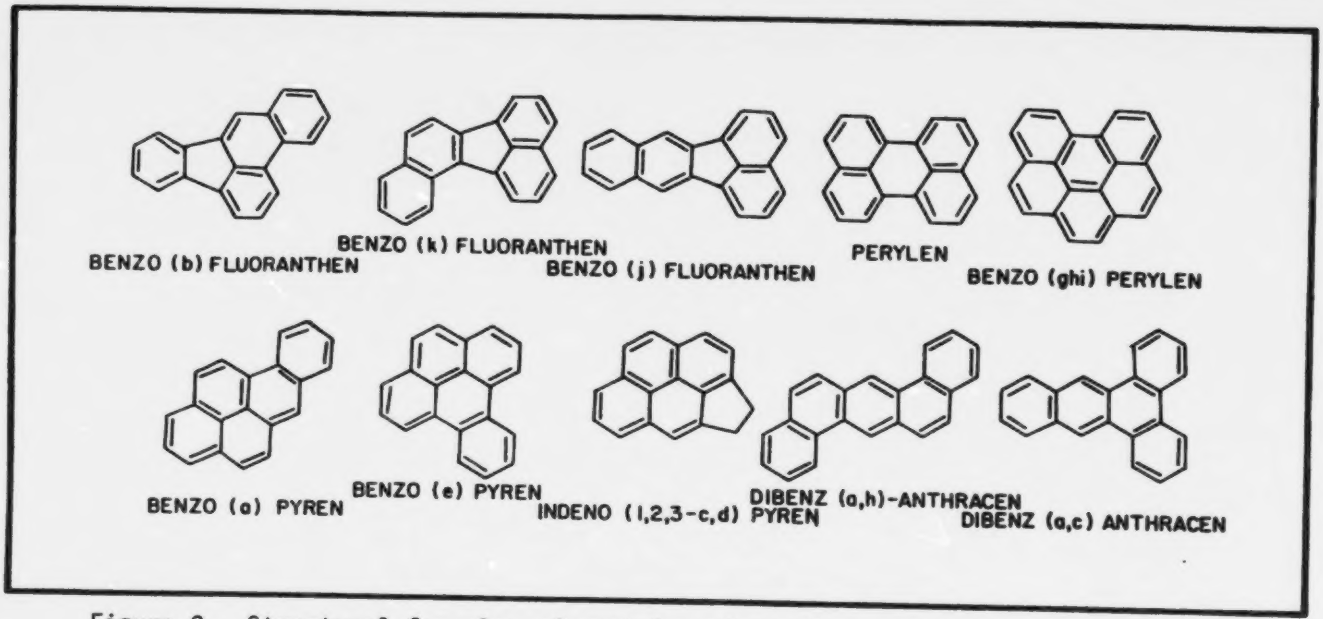
BENZO (b) FLUORANTHEN
BENZO (k) FLUORANTHEN
BENZO (j) FLUORANTHEN
PERYLEN
BENZO (ghi) PERYLEN
BENZO (a) PYREN
BENZO (e) PYREN
INDENO (1,2,3-c,d) PYREN
DIBENZ (a,h)-ANTHRACEN
DIBENZ (a,c) ANTHRACEN

Figure 2. Structural formulae of certain polycyclic aromatic hydrocarbons.

These 10 substances are suspected carcinogens (cancer-causing agents) but according to research conducted by Peter Christian Ellwart (1976), these substances are commonly found in greater concentrations in sewages and sludges. Ellwart also found that these polycyclic aromatic hydrocarbons increased in concentration with peat depth. This is consistent with the accepted notion that more highly decomposed peats are frequently found in deeper layers which would result in a high concentration of bitumens in these layers of peat.

It should be emphasized that since these compounds are hydrophobic and bound to peat solids, they should not pose environmental hazards during harvesting.

2.2.2 Lignins

Lignins, which contribute to the rigid structure of plant cells, have been found to be relatively stable during decomposition. During the separation of peat components, via conventional methods, lignins are often grouped with chemically similar humic acids (i.e., both substances are polyphenolic in character). Lignins are usually soluble in strong base.

2.2.3 Humates

Humates, which are soluble in strong base, consist of two types of organic material, humic acids and fulvic acids. Humic acids function in metal chelation, and base exchange. The fulvic acids are derived from organic matter which is soluble in water and remains in solution after neutralization and after all humic acids have been leached out (Clausen and Brooks, 1980). In general, humates have an affinity for proteins and absorb substances such as insecticides, herbicides and plasticizers. Work performed by Pheeney and Radforth (1972) indicates that peat (humates) operates as a concentrator of such toxic substances (e.g., DDT). Traces of DDT and DDE (anaerobic decomposition product of DDT) were found in depths to 170 cm in areas which had not been sprayed. Gamble (1972) reported that Bunker C fuel oil is absorbed by peat moss. He postulated that the absorption properties of peat are due in part to the ability of humates to form H-bonds and π-bond complexes (via their numerous aromatic rings).

2.2.4 Phenolic Acids and Derivatives

The phenolic acids are naturally occurring constituents in plants as well as decomposition products of hemicelluloses and celluloses. Humates are polymerization products of these compounds.

Trace amounts of water-soluble organic compounds (Table 10) have been extracted via steam distillation from air-dried peat (Naucke _et_ _al_., 1972). The compounds identified were: phenols and derivatives; aromatic acids; aromatic aldehydes and ketones; aliphatic acids; furan derivates; and chinoidic substances.

Research conducted by H. Morita (1980) indicated that phenolic compounds could be used as markers to follow the decomposition process in cultivated peat soils (high-moor).[1] The relative amounts of phenolic compounds in cultivated peat soil were obtained over a five-year period (Table 11).

Morita emphasized that the composition and abundance of the phenolics in peat soil depend on botanical composition as well as the degree of decomposition. Therefore, the phenolic acids used as markers will vary with each soil. It was also found that the level of decomposition of the cultivated high-moor bog increased over the five years as shown in Table 12.

This information correlates very well with a Russian study reviewed by Clausen (1980) (Table 13). According to this study the concentration of humic and fulvic acids in oligotrophic peatlands vary dramatically when they are drained and mined, whereas cultivation of eutrophic peatlands results in minimal concentration changes of humic and fulvic acids.

---

[1] It should be noted that in Morita's (1980) study the bog was treated with lime upon cultivation therefore it is not clear how this affected the mechanics of decomposition.

TABLE 10

SUBSTANCES IN EXTRACTS FROM LOW-DECOMPOSED SPHAGNUM PEATS, SEPARATED AND IDENTIFIED VIA GLC/MS[1,2]

NO.	NAMES OF SUBSTANCES
1	Phenol
2	Guajacol
3	2-Methyl-3hydroxy-pyrone
4	2,6-Di-tert.-butylcresol[3]
5	Furfural
6	5-Methylfurfural
7	5-Hydroxymethyl-Furfural
8	Benzaldehyde
9	4-Hydroxy-benzaldehyde
10	Vanilline
11	Furyl-Methyl-Ketone
12	Acetophenone
13	3-Hydroxyacetophenone
14	Furane 2-carboxylic acid
15	Benzoic acid
16	4-Methyl-benzoeic acid
17	3-Methoxy-benzoic acid
18	4-Methoxy-benzoic acid
19	3-4-Dimethoxy-benzoic acid
20	Vanillic acid
21	Iso-vanillic acid
22	Syringic acid
23	3-Hydroxy-benzoic acid
24	4-Hydroxy-benzoic acid
25	3,4-Dihydroxy-benzoic acid
26	2,5-Dihydroxy-benzoic acid
27	Acetic acid
28	Propionic acid
29	Levulinic acid

[1] Symbols: GLC/MS = gas-liquid chromatography using a mass spectrum chromatograph.

[2] Taken from Naucke _et al_. (1972)

[3] antioxidant additive from ether

TABLE 11

COMPARATIVE ABUNDANCE OF PHENOLICS IN CULTIVATED PEAT SOIL[1]

	PHENOLIC	YEARS AFTER CULTIVATION		
		0	3	5
1.	4-Hydroxycinnamic acid	++++	++	+
2.	4-Hydroxy-3-methoxycinnamic acid	++++	++	+
3.	4-Hydroxy-3,5-dimethoxycinnamic acid	+++	+	-
4.	2,5-Dihydroxybenzoic acid	++	+	-
5.	2-Hydroxybenzoic acid	++	+	-
6.	2,4-Dihydroxybenzoic acid	++	+	-
7.	4-Hydroxyphenylacetic acid	++	+	-
8.	4-Hydroxyacetophenone	+	+	-
9.	2,4,5-Trihydroxyacetophenone	+	-	-
10.	3-Methoxycatechol	+	-	-
11.	3,4-Dihydroxyacetophenone	+	+	-
12.	4-Hydroxyphenylpropionic acid	+	+	-
13.	3-Hydroxyresorcinol	++	+	-
14.	4-Hydroxy-3-methoxyacetophenone	+++	++	+
15.	4-Hydroxy-3-methoxybenzoic acid	+++	++	+
16.	4-Hydroxybenzoic acid	+++	++	+
17.	3,4-Dihydroxybenzoic acid	+	+	+
18.	4-Hydroxy-1,3-benzenedicarboxylic acid	++	++	+

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[1] Taken from Morita (1980)

TABLE 12

PROXIMATE ANALYSES OF CULTIVATED PEAT SOIL[1,2]

FRACTION %	YEARS AFTER CULTIVATION		
	0	3	5
Bitumen	5.9	6.2	6.4
Hemicellulose	19.4	17.1	16.2
Acid-soluble nonhemicellulosics	18.8	18.9	19.2
Cellulose	12.9	11.0	9.7
Acid-soluble noncellulosics	3.4	3.9	3.7
Lignin-humic complex	39.6	42.9	44.8

[1] Expressed as percentages on an ash-free, dry basis.

[2] Taken from Morita (1980)

TABLE 13

EFFECTS OF DRAINAGE AND PEAT MINING ON WATER QUALITY FOR OLIGOTROPHIC AND EUTROPHIC PEATLANDS IN THE USSR.[3]

	HIGH-MOOR BOG (Oligotrophic)		LOW-MOOR FEN (Eutrophic)	
	Undrained	Drained & Mined	Undrained	Drained & Mined
Humic & Fulvic acids mg/l	85-140	100-230	16-45	15-70

[3] Taken from Largin (1976)

3.0 CHEMISTRY OF PEAT WATERS

The different types of peatlands can be characterized on the basis of their water chemistry. Water chemistry in fens has characteristically higher values of pH, conductivity, calcium, magnesium and alkalinity than in bogs. Fen waters are dominated by Ca^{++} and HCO_3^- ions and bog waters are dominated by H^+ and SO_4^{--} ions (Richardson et al., 1978). Acidity in Sphagnum bogs has been attributed to acidity in precipitation, secretion of whole organic acid molecules by live Sphagnum plants and cation exchange in the walls of Sphagnum plants (Clymo, 1964). The difference in pH between bogs and fens may be related to rates of water movement. The pH of peatlands has been found to increase faster than rates of water movement, which was considered to be related to removal of hydrogen ions by moving water and replacement with cations (Sparling, 1966).

Significant differences in water quality between bogs and fens were reported from Finland (Tolonen and Seppänen, 1976; Tolonen and Hosiaisluoma, 1978) Poland (Tolpa and Gorham, 1961) Soviet Union (Yefimov and Yefimova, 1973) Great Britain (Gorham, 1956a; Gorham 1956b; Gorham and Pearsall, 1956; Gorham and Cragg, 1960) and the United States (Verry, 1975; Clausen, 1980; Clausen et al., 1980; Glaser et al., 1981). In summary, fens have a greater availability of nitrogen, phosphorous, potassium, sulfur, calcium, magnesium, iron, boron, copper and molybdenum, while bogs have greater availability of manganese and zinc.

Various impacts of runoff from peatlands on the receiving environment have been investigated. The potential impact of bog humic substances on plants and animals in receiving waters has been reviewed by Crawford (1978). The primary findings indicated concern with respect to diminished light penetration due to the elevated colour caused by humic substances and potential toxicity of peatland waters to aquatic organisms. The diminished light levels were suggested to lead to decreases in primary production. Dunson and Martin (1973) described the impact of a bog-derived acidity gradient on brook trout (Salvelinus fontinalis). Trout avoided a stream contaminated with bog water until dilution raised the pH to 4.0-4.75. Toxicity tests conducted on fathead minnows (Pimephales promelas) indicated that considerable volumes of bog water must enter streams before toxicity to fish is observed (Crawford, 1978). Toxicity was considered to be related to pH although the toxicity of dissolved compounds could not be dismissed.

The impacts of peat harvesting operations on water quality were assessed by Clausen (1980) and Clausen et al. (1980). Disturbed peatlands, including those where peat was being mined, exhibited higher values of colour, suspended sediment, acidity, sodium, aluminum, potassium, iron, zinc, copper, boron and nitrate, ammonia -N and organic nitrogen. Undisturbed peatlands had higher rates of dissolved oxygen and percent saturation. Mining operations did not increase levels of nickel, lead, cadmium, arsenic and selenium. The water quality effects of drainage and mining of fens and bogs in the USSR was investigated by Largin (1976). Drainage and mining in bogs appeared to increase pH, and calcium, magnesium, bicarbonate, sulfate, and humic and fulvic acid concentrations. Similar operations in fens increased pH, magnesium, sulfate, nitrate, and humic and fulvic acids. Increased aeration of the bog occurred as the drainage aged, which led to increases in pH, iron, calcium, magnesium, bicarbonate, and humic and fulvic acids. Largin (ibid.) indicated that there was apparently very little connection between the chemistry of peat ash and the chemical composition of aqueous solution of the corresponding layer. Drainage of a harvested bog did not decrease the pH in a receiving stream in New Brunswick (Korpijaakko and Pheeney, 1976).

Water chemistry was analysed from a stream receiving drainage from a bog actively mined for fuel peat in Newfoundland (Osborne, personal communication, 1982). Sampling stations were located just above the effluent input, just below the effluent input and 1.3 km downstream of input. Results indicate that pH, alkalinity, specific conduction, hardness, calcium and magnesium all declined immediately below the input from the bog, however the values approached normal 1.3 km downstream. Levels of nitrate, turbidity, suspended solids, total organic carbon and barium increased immediately downstream of the bog outlet but values approached background levels in samples taken 1.3 km downstream. Levels of iron and aluminum downstream of the bog outlet were intermediate to values from the other stations and were highest 1.3 km downstream.

Although no elevated levels of heavy metals were reported in waters from mined peatlands, the elevated levels of suspended particles may provide a mechanism for release of metals into receiving waters. The binding capacity of the humic substances is very high in the pH range 4-5. However, once particles of peat are transported from a bog, decomposition may be fairly rapid and, should pH increase, the binding capability may be weakened. This could lead to secondary release of metals from bog mining activities (Mathur, personal communication, 1982). The quantities of particulates in runoff from peat bogs could be further increased by contribution of fugitive dust from mining operations, particularly if milled-peat techniques of harvesting are used (Conklin, 1978). Such deposition generally occurs within 30 km of the operation with potential for significant air quality problems within 15 km.

Concentrations of nutrients in waters from peatlands were reported by: Verry, 1975; Walmsley and Lavkulich, 1975; Tolonen and Seppänen, 1976; Crawford, 1978; Tolonen and Hosiaisluoma, 1978; Clausen, 1980; and Clausen et al., 1980.

The mean concentrations of major nutrients reported in the literature varied. However, apart from levels of phosphorous reported from Newfoundland (Osborne, personal communication, 1982) which were below detection limits, the nutrient levels were within the ranges which may stimulate algal production. Bog waters may be regarded as eutrophic and may be significant sources of nutrients to receiving waters (Crawford, 1978). Total nitrogen in runoff waters from peatlands varies from 0.3 to 2.0 mg/l and nitrate concentrations vary up to 0.45 mg/l (Clausen et al., 1980). Total phosphorous concentrations in peatland runoff waters were found to vary from 0.01 to 0.40 mg/l and orthophosphate varied from 0.01 to 0.35 mg/l (ibid., 1980). Bog water added to nutrient-poor lake water resulted in significant increases in algal photosynthesis and gross production

(Crawford, 1978). This potential for stimulated productivity may be particularly of concern during drainage of peatlands into oligotrophic lakes. Contribution of waters from mined peatlands may have a significant impact on receiving waters particularly in headwater streams where the peatland may occupy a large portion of the watershed. The peatland drainage system may have the added effect of concentrating what may have been a non-point source into a point source addition to the receiving waters. Results of analyses of water quality in peatlands and from peatland runoff are presented in Table 14.

3.1 Applicability to Canada

The information presented indicates the variety of factors which affect the chemistry of peat and peat waters including peat type, peatland type, anthropogenic inputs, geology, and mining activities. Based on this review, general trends in chemistry of peat and peat waters have been described which are applicable to Canada. Because concentrations of specific parameters may vary significantly due to the factors described above, prediction of potential levels in particular peatlands is difficult. It is further complicated by a lack of peatland inventory information for much of Canada.

TABLE 14

DATA FROM A RANGE OF PEATLAND WATER QUALITY INVESTIGATIONS

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	COLOUR UNITS - - - - pH	SUSPENDED SEDIMENTS - - - - - SPECIFIC CONDUCTIVITY	Mg	Na	Ca
Moor House nature reserve, England	Gorham 1956	- - - - - bog	- - - - - 1954 - May 18 and Aug. 2	17 - - - - 46 cm	- - - - 3.68-8.20	- - - - - 18-379	0.2 -[a] 10.0	1.6 - 5.3	0.3 - 74.0
Zieleniec; Eastern Sudeten Mountains Poland 53° 47' 20" N, 23° 5' 40" E	Tolpa and Gorham 1961	- - - - - bog	1 sq km - - - - - late summer early fall	4 - - - - surface	- - - - 3.84-4.00			0.2 - 0.2	0.4 - 0.6
Wieliszewo, 40 km from Baltic Sea, Poland 54° 24' 30" N, 17° 20' E	Tolpa and Gorham 1961	- - - - - bog	1.35 sq km - - - - - late summer early fall	4 - - - - surface	- - - - 3.42-4.23			1.7 - 4.7	0.8 - 1.8
Kolnica, NE part of Polish plain 50° 21' N, 16° 24' 35" E	Tolpa and Gorham 1961	- - - - - bog	1.46 sq km - - - - - late summer early fall	4 - - - - surface	- - - - 3.76-3.81			0.4 - 0.7	0.4 - 0.9
Toivola area, Northern Minn.	Clausen 1980	moderately decomposed hemic - - - - - transitional, not drained	3760 ha - - - - - weekly 1978 monthly 1979	46 - - - - surface	266 - - - - 6.1	3.9 - - - - - 51	2.96	1.18	10.26
Tamarac River Minn.	Clausen 1980	hemic - - - - - undisturbed fen	14,350 ha - - - - - weekly 1978 monthly 1979	14 - - - - surface	129 - - - - 7.0	2.4 - - - - - 105	6.23	1.59	17.14
Corona Minn.	Clausen 1980	fibric sphagnum - - - - - bog mined since 1958	290 ha - - - - - weekly 1978 monthly 1979	46 - - - - surface	372 - - - - 5.2	15.8 - - - - - 66	1.73	3.30	4.26
Fens Minn.	Clausen 1980	hemic - - - - - cultivated for 25 yrs.	93 ha - - - - - weekly 1978 monthly 1979	12 - - - - surface	529 - - - - 6.5	16.7 - - - - - 202	9.76	2.97	34.95
South Finland *	Tolonen and Seppänen 1976	- - - - - poor fens	- - - - - summer 1973	30 - - - - surface	- - - - 4.84 (0.14)	- - - - - 69.5 (0.93)	2.00 (0.32)		4.91 (0.50)

[a] The first number given is the mean except where only the range (two numbers separated by a dash) was available. A single number in brackets is the standard deviation except where only the standard error (indicated by an asterisk beside the location name) was available. Concentrations are given in ppm.

Cl	Cu	Zn	Pb	Cr	Cd	Hg	As	P	Mn	Al	Ba	Mo	Se
2.2 - 6.5													
0.2 - 0.3													
2.2 - 7.8													
0.6 - 0.8													
	<0.01	0.04	<0.13	0.01	0.01	0.0026	0.003	.15	1.00	0.26			0.001
	<0.01	0.04	<0.13	<0.01	<0.01	0.0024	0.002	.04	0.11	0.08			0.001
	0.01	0.06	<0.13	0.02	<0.01	0.0029	0.003	.11	0.15	0.73			0.001
	0.01	0.06	<0.13	<0.01	<0.01	0.0037	<0.001	.64	1.14	0.38			<0.001
4.50 (0.77)								0.053 (0.0086)	0.051 (0.0088)			0.072 (0.0075)	

Mo	Se	Co	K	SO_4	SiO_2	Ni	B	NH_4	Si	NO_3	F	N	Fe
		0.1 - 0.7	3.6 - 28.5										
			0.2 - 0.2	6.0 - 9.3									
			0.2 - 2.3	9.3 - 22.1									
			0.05 - 0.3	9.6 - 11.3									
	0.001		1.29			<0.04	0.01	0.2				1.5	2.98
	0.001		<.75			<0.04	0.01	<0.1				1.2	0.40
	0.001		1.89			<0.04	0.02	2.2				3.6	4.04
	<0.001		1.77			<0.04	0.04	1.1				6.3	8.16
0.072 (0.0075)			1.38 (0.29)				0.0527 (0.0043)	2.00 (0.57)					1.22 (0.27)

TABLE 14 (CONT'D)

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	COLOUR UNITS - - - - pH	SUSPENDED SEDIMENTS - - - - - SPECIFIC CONDUCTIVITY	Mg	Na	Ca
South Finland *	Tolonen and Seppänen 1976	- - - - - bogs	- - - - - summer 1973	41 - - - - surface	- - - - 3.72 (0.07)	- - - - - 23.4 (0.33)	0.82 (0.08)		2.50 (0.15)
North Finland *	Tolonen and Seppänen 1976	- - - - - poor fens	- - - - - summer 1974 (rainy)	27 - - - - surface	- - - - 4.27 (0.08)	- - - - - 13.8 (2.69)	0.82 (0.13)	1.43 (0.23)	4.56 (0.57)
North Finland *	Tolonen and Seppänen 1976	- - - - - bogs	- - - - - summer 1974 (rainy)	44 - - - - surface	- - - - 3.75 (0.03)	- - - - - -7.9 (2.11)	0.29 (0.03)	0.52 (0.07)	1.80 (0.19)
Mire complex, Southern Central Finland	Tolonen *et al.* 1979	- - - - - ombrotrophic	1215 ha - - - - - autumn 1972 and 1978	9 - - - - surface	212 (110 - 460) - - - - 3.92 (3.6-4.3)	- - - - - -5.6	0.34 (0.10 - 0.98)	0.57 (0.02 - 1.90)	0.77 (0.11 - 3.12)
Mire complex, Southern Central Finland	Tolonen *et al.* 1979	- - - - - minerotrophic	1215 ha - - - - - autumn 1972 and 1978	6 - - - - surface	245 (188 - 325) - - - - 4.27 (4.1-4.4)	- - - - - 14 (12-16)	0.52 (0.45 - 0.60)	1.04 (0.65 - 1.30)	1.18 (0.85 - 1.49)
South and Central Finland *	Tolonen and Hosiaisluoma 1978	- - - - - poor fens	- - - - - 1972	49 - - - - surface	- - - - 4.84 (3.6-6.2)	- - - - - 69.5 (0.93)	1.47 (0.19)	3.16 (0.30)	4.39 (0.55)
South and Central Finland *	Tolonen and Hosiaisluoma 1978	- - - - - bogs	- - - - - 1972	89 - - - - surface	- - - - 3.72 (3.35-4.3)	- - - - - 23.4 (0.33)	0.63 (0.07)	1.69 (0.14)	1.84 (0.11)
Outside Grand Falls, Nfld. upstream (water)	James Osborne pers. comm. 1982	- - - - - stream receiving water from mined bog	- - - - - July - Nov.	9 - 15 - - - - surface	2.53 (2.42) - - - - 6.1-6.9	19.18 (1.83) - - - - - 37 (68)			
Outside Grand Falls, Nfld. immediately below (water)	James Osborne pers. comm. 1982	- - - - - stream receiving water from mined bog	- - - - - July - Nov.	9 - 15 - - - - surface	9.1 (16.80) - - - - 3.8-4.6	29.07 (3.03) - - - - - 26.2 (6.2)			

Cl	Cu	Zn	Pb	Cr	Cd	Hg	As	P	Mn	Al	Ba	Mo	Se	Co
2.31 (0.23)								0.039 (0.0056)	0.047 (0.005)			0.074 (0.0052)		
4.16 (0.46)								0.0788 (0.0131)	0.0228 (0.0062)					
3.09 (0.18)								0.0721 (0.0128)	0.0123 (0.0033)					
1.47 (0.81 - 3.20)	0.0077 (0.0019 - 0.0117)	0.0302 (0.0113 - 0.0561)						0.059 (0.02 - 0.165)	0.012 (0.0071 - 0.019)	0.067 (0.05 - 0.102		0.0014 (0.0009 - 0.0022)		
1.98 (0.8 - 3.2)	0.0082 (0.0078 - 0.0086)	0.0184 (0.0169 - 0.0198)						0.0734 (0.007 - 0.180)	0.0266 (0.0052 - 0.051)	0.178 (0.111 - 0.209)		n = 1 0.9		
4.80 (1.26)	0.010 (.00059)	0.0329 (0.0032)						0.147 (0.012)	0.0319 (0.0063)			0.00092 (.00024)		
1.51 (0.14)	0.011 (.00095)	0.033 (0.0018)						0.127 (0.005)	0.015 (0.0013)			0.00058 (.00005)		
	<0.01		<0.02	<0.01 - 0.26	<0.01	0.0007 (0.0019)	<0.05	<0.005	0.03 (0.01)	0.048 (0.043)	0.02 (0.02)	<0.01	<0.05	<0.01
	<0.01		<0.02	<0.01 - 1.02	<0.01	0.00005 - 0.0004	<0.05	<0.005	0.058 (0.068)	0.06 (0.04)	0.17 (0.37)	<0.01	<0.05	<0.01

Ba	Mo	Se	Co	K	SO_4	SiO_2	Ni	B	NH_4	Si	NO_3	F	N	Fe
	0.074 (0.0052)			0.59 (0.08)				0.044 (0.0027)	3.47 (1.13)					0.26 (0.02)
				0.40 (0.05)	0.80 (0.09)	2.69 (0.29)		0.0259 (0.0023)						0.81 (0.19)
				0.30 (0.03)	0.72 (0.06)	1.86 (0.14)		0.0363 (0.0030)						0.25 (0.81)
	0.0014 (0.0009 - 0.0022)			0.29 (0.08 - 0.83)	3.51 (0.41 - 10.9)	1.07 (0.18 - 2.6)		0.0305 (0.026 - 0.043)					3.94 (0.8 - 2.8)	0.20 (0.09 - 0.54)
	n = 1 0.9			0.15 (0.08 - 0.28)	4.02 (3.8 - 6.9)	3.60 (1.8 - 4.7)		0.0205 (0.019 - 0.022)					2.66 (0.8 - 9.52)	0.67 (0.32 - 1.03)
	0.00092 (.00024)			0.89 (0.10)	4.27 (0.43)			0.0316 (0.0025)	0.67 (0.18)				8.24 (1.47)	1.83 (0.42)
	0.00058 (.00005)			0.52 (0.05)	4.43 (0.29)			0.0399 (0.00136)	0.42 (0.02)				8.17 (1.09)	0.42 (0.04)
2 2)	<0.01	<0.05	<0.01	0.14 (0.07)							0.77 (1.07)			0.41 (0.18)
7 7)	<0.01	<0.05	<0.01	0.13 (0.03)							0.95 (1.46)			0.83 (0.68)

TABLE 14 (CONT'D)

LOCATION	REFERENCE	PEAT TYPE - - - - - BOG TYPE	BOG SIZE - - - - - SAMPLING PERIOD	NO. OF SAMPLES - - - - DEPTH OF SAMPLE	COLOUR UNITS - - - - pH	SUSPENDED SEDIMENTS - - - - - SPECIFIC CONDUCTIVITY	Mg	Na	Ca
Outside Grand Falls, Nfld. downstream (water)	James Osborne pers. comm. 1982	- - - - - stream receiving water from mined bog	- - - - - July - Nov.	9 - 15 - - - - surface	3.25 (1.74) - - - - 5.9-6.6	17.8 (3.36) - - - - - 29.9 (2.9)			
Marcell Exp. Forest Itasca Co., Minn. ~47° 32' N, 93° 28' W	Verry, 1975	sphagnum - - - - - 5 bogs	3 - 25 ha - - - - - summer 1967; spring, summer, fall 1968-1970, 1971-1972	49-172 - - - - surface	- - - - 3.6 (0.3)	- - - - - 51 (13)	0.97 (0.36)	0.6 (0.3)	2.4 (1.0)
Marcell Exp. Forest Itasca Co., Minn. ~47° 32' N, 93° 28' W	Verry, 1975	sphagnum - - - - - fen	2 ha - - - - - summer 1967; spring, summer, fall 1968-1970, 1971-1972	3 - 22 - - - - surface	- - - - 6.5 (0.28)	- - - - - 25 (48)	2.88 (0.93)	2.0 (1.0)	16.6 (9.0)
S.E. of Yukon Territory in vicinity of Watson Lake townsite	Walmsley and Lavkulich 1975	Terric Fibric mesisol to typic humisol - - - - - fen peat to forest peat		6 sites - - - - surface	- - - - 4.2-7.4	- - - - - 22-370	0.3 - 20.0	0.4 - 2.8	0.8 - 43.0
Quebec	B. Coupal pers. comm. 1982	- - - - - bog	- - - - - Sept. 18, 1979	- - - - surface	- - - - 3.9	- - - - - 29		0.21	1.6
Quebec	B. Coupal pers. comm. 1982	- - - - - bog	- - - - - Sept. 18, 1979	- - - - surface	- - - - 4.2	- - - - - 20		0.09	<0.32
Southern Byelorussia	Kovalev and Generalova 1969	- - - - - bog		- - - - surface	- - - - 3.2-4.3		0.23 - 0.48		1.57 - 2.35
Red Lake Bog U.S.A.	Hofstetter 1969, as cited by Crawford 1978	- - - - - bog		- - - - surface	- - - - 5.85-7.87	- - - - - 21-51	0.6 - 3.8		4.1 - 6.6
Northeast Minnesota 11 fens	Clausen et al. 1980	hemic & sapric - - - - - fen	- - - - - July 19 - 20 1979 and Sept. 11 - 12	30 - - - - surface	245 (115.0) - - - - 6.7 (0.391)	23.0 (24.95) - - - - - 104 (67.350)	5.38 (2.317)	1.85 (1.337)	17.53 (10.336)
Northeast Minnesota 15 bogs	Clausen et al. 1980	fibric - - - - - bog	- - - - - July 19 - 20 1979 and Sept. 11 - 12	34 - - - - surface	307 (75.56) - - - - 5.5 (0.648)	9.0 (10.78) - - - - - 33 (12.615)	1.55 (1.427)	1.20 (1.446)	4.92 (4.145)

Cl	Cu	Zn	Pb	Cr	Cd	Hg	As	P	Mn	Al	Ba	Mo	Se	Co
	<0.01		<0.02	<0.01 - 0.26	<0.01	<.00005 - .0001	<0.05	<0.005	0.08 (0.05)	0.08 (0.07)	0.05 (0.06)	<0.01	<0.05	<0.01
.7 .8)	0.04 (0.07)	0.08 (0.11)	<0.05					0.19 (0.18)	0.06 (0.05)	0.79 (0.43)				
.4 .4)	0.18 (0.36)	0.11 (0.17)	<0.05					0.09 (0.04)	0.08 (0.06)	0.16 (0.06)				
.4 - .8														
.53 - .34														
.25 - .43														
							0.0055 (0.0082)	0.0032 (0.0024)	0.07 (0.044)	0.02 (0.248)	0.30 (0.528)		0.0011 (0.00115)	
							0.0092 (0.0109)	0.0023 (0.0019)	0.07 (0.110)	0.07 (0.068)	0.38 (0.278)		0.0011 (0.00079)	

Mo	Se	Co	K	SO_4	SiO_2	Ni	B	NH_4	Si	NO_3	F	N	Fe
<0.01	<0.05	<0.01	0.17 (0.07)							1.08 (2.27)			1.8 (1.1)
			1.3 (0.6)	4.6 (2.2)					2.7 (2.1)	0.20 (0.25)		1.34 (0.64)	1.35 (0.8)
			1.1 (0.4)	6.0 (4.2)					4.9 (4.0)	0.10 (0.07)		0.58 (0.29)	0.98 (0.48)
			0.3 - 3.9						0 - 8	1.2 - 9.6	0.0 - 1.4		
								<0.02					
								<0.02					
			0.4 - 0.7	4.8 - 6.9									
	0.0011 (0.00116)											1.4 (0.561)	2.41 (2.209)
	0.0011 (0.00079)											1.0 (0.274)	1.90 (1.157)

4.0 ENERGY PEAT DEVELOPMENTS LIKELY TO PROCEED IN CANADA

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In a report on energy alternatives in Canada, the Special Committee on Alternative Energy and Oil substitution identified peat as a potential fuel for energy production, particularly in areas that are deficient in other energy resources (House of Commons, Canada, 1981). The Committee concluded that as peat deposits often occur in less developed regions of Canada, development of Canada's peat resource could provide employment as well as provide energy. It was recommended that Canada's peat resource be inventoried and that Research and Development on peat encompass the development of an efficient technology for peat gasification.

To determine those developments involving use of peat as an energy source which are most likely to proceed prior to 1999, discussions were held with private developers and individuals from federal government departments and provincial agencies.

Peat in Canada offers a vast, largely untapped energy source (Tibbetts and Fraser, 1978; Tibbetts and Ismail, 1980). However the majority of people contacted during this project, while acknowledging that there may indeed be the potential for large-scale development of peat as an energy source, identified major constraints to large-scale development of the resource. In the first place, while large-scale peat-fired thermal plants exist in other parts of the world, notably the Soviet Union, Finland and Ireland, the production economics may not be the same as in Canada, also alternative sources of energy may be more readily available in Canada. The economics of conversion of fossil-fired plants from non-renewable to renewable sources may not be favourable for remote sites in Canada at this time (Biomass Energy Institute and Office of Industrial Research (University of Manitoba), 1978). Secondly, although the peat resource in Canada appears to be extensive, it has not yet been mapped and described accurately. Before peat can be shown to have the potential to make a significant contribution to the national energy mix, peat quantities must be estimated on a reserve level. Estimation of the actual peat resource is further complicated because there appear to be conflicting approaches to the estimation of quantities of thermal peats. Thirdly, the majority of Canada's peat resources are far from established population centres. This results in increased costs of handling and transportation of fuel or transmission of electricity. Finally, given the existing technology and the generally short (3-4 months) harvesting season, large storage capacity is required, vast areas of bogs must be under production at any one time and significant materials handling problems are likely. New technology is being developed and tested, notably wet harvesting and wet carbonization, both of which could significantly increase the length of the harvest season, but this technology must still be proven for full-scale operations.

In short, apart from one developer who is confident that wet harvesting and wet carbonization technology will be proven in the immediate future, the consensus of opinion among the people interviewed was that small-scale demonstration projects using peat for fuel may be developed in the near future, although it is unlikely that large-scale peat energy projects will be undertaken prior to 1999. However, should wet harvesting and wet combustion prove economically feasible there may be accelerated development of peat resources for energy use, particularly in view of the apparent advantages of thermal peat over certain coals with respect to sulphur content. Also, if the economics of energy supplies undergo significant changes in the near future, peat may become a more attractive alternative.

The potential for use of peat as an energy source in the near future is briefly outlined by province below.

Newfoundland - A peat energy project is now in place in Bishops Falls. This operation harvests peat for use in boilers of a pulp and paper operation with an anticipated production of 10,000 t per year (Scott et al., 1980). The water chemistry of runoff from the mining operation is being monitored by Environment Canada. Another project which may begin in the near future is proposed for the southeast coast of Newfoundland. This would be a trial project to assess technology for harvesting of peat for local space heating requirements. At present there are no plans for large-scale development for energy peat prior to 1999. Work is continuing on an inventory of the resource.

Prince Edward Island - There is some interest in developing the energy potential of peat, however on a small-scale basis. The goal would be to investigate the potential for using peat for space heating. The peat resources were estimated, on a preliminary basis only, in 1974 (R. Bruce Graham and Associates Ltd., 1974).

Nova Scotia - The most likely use of fuel peat in Nova Scotia appears to be small-scale development for industrial uses or for space heating. The province has a rough estimate of peat resources and a number of bogs appear to have fuel peat potential.

New Brunswick - Peat has been tried as a fuel for a demonstration energy project in the northeast Lameque, involving a greenhousing operation. The project has been suspended at present. The potential for using peat in a 40 megawatt thermal plant in the northeast has been assessed, however development of the project is unlikely in the near future. Tests have also been conducted on the combustion characteristics of peat and peat-oil combinations. There appears to be some interest in investigating this fuel combination further at an existing thermal plant at Chatham. Should these tests prove successful there may be utilization of peat for fuel prior to 1999. The most significant potential use apart from the Chatham experiment would appear to be small-scale utilization for industrial or residential space heating. The Department of Natural Resources is now completing an inventory of its peat resource in New Brunswick.

Quebec - The most significant potential for use of peat for energy on a large-scale appears to be the gasification project proposed by Hydro Quebec on Anticosti Island. The project would gasify wood initially then transfer to peat as a source. The gas would be used to fire a turbine. This project has been delayed for about three years. Hydro Quebec also investigated the potential of a large thermal plant at Lac St. Jean to be fuelled by peat. This project is not anticipated to proceed in the foreseeable future. Although there are a number of individuals investigating the potential for fuel peat production in Quebec, it is most likely that development of peat for energy in the near future will be on a small scale at least initially. Interest has been expressed in harvesting fuel peat from bogs from which the horticultural peat has been removed. The Quebec Ministere des Richesses Naturelles has completed detailed surveys of peatlands in more accessible parts of Quebec.

Ontario - The Ontario Department of Natural Resources is currently undertaking an inventory of its fuel peat resources in the province. There is a development planned for a bog in Northern Ontario. The site has a 50-ha area available and dry harvesting will be used. The peat will be used to heat a nearby tree nursery. A much more ambitious project is planned for the Fort Francis area. Peat Resources Ltd. plans to initially produce 100,000 - 500,000 t per year of pelletized peat. Their goal is to initially use the fuel for space heating but to eventually provide a low sulphur fuel for Ontario Hydro. Their development hinges on the success of wet harvesting and wet carbonization technology. They feel that they must ultimately produce 1,000,000 t/yr to be viable.

Manitoba - To date there has been very little interest in peat as an energy source in Manitoba. There is no existing policy to promote development of energy peats. There may be some investigation initially of the feasibility of peat use for energy in remote areas.

Saskatchewan - There is a fuel peat demonstration project planned for Buffalo Narrows in northern Saskatchewan. The sod peat mining technique will be used, bogs have been ditched and are draining. The fuel will be used in two private homes and in a municipal garage. The major interest may be in providing space heating energy in remote sections of the province. There are no plans for major development of fuel peat deposits.

Alberta - There has been some work on the peat deposits in Northern Alberta. It is unlikely that there will be significant development of fuel peat deposits in the foreseeable future.

British Columbia - Peat does not play any part in the British Columbia energy picture at the moment. Nor, given the availability of alternative fuels, is it likely to do so in the foreseeable future.

Federal Government - Up to 1999, interest in peat as an energy source is expected to focus on demonstration projects for small-scale utilization. Major projects may be the proposed Fort Francis operation, or Anticosti Island. Should significant technology advances be made in the near future, the situation must be re-evaluated primarily due to the apparently large resources available.

Prior to full-scale development of peat as an energy source which could make a significant contribution to Canada's energy mix, the following must be addressed:

Available Resource - much more intensive inventories must be carried out to evaluate the extent of the resource. This inventory procedure must be carried out by remote sensing (including air photo interpretation) techniques used in conjunction with ground truthing programs so that a realistic estimate can be made within the next 17 years. Much work in developing techniques to conduct such a study is still required. Such work is considered under the category of Mapping and Inventory.

Topography - The resource potentials presently quoted in the literature (both measured and projected) assume that all fuel peats mapped will be available for harvesting. Peat resources have generally been found to be approximately 50% fuel (H 5-10) peat and 50% horticultural (H 1-3) peat in most inventories conducted. This may be accurate in terms of potential but the mining and drainage technologies are yet to be developed which would allow an efficient removal of 100% of the peat identified.

Loften (1980) has suggested as a general case that the terrain in Muskeg areas typically slopes at 0.1 to 0.3%. This indicates that there may be difficulty in effective gravity drainage of the deep-lying fuel peat deposits. Loften states that a detailed hydrology study of the bog and surrounding terrain must be conducted prior to finalizing the inventory and planning of a peat bog exploitation program.

Site-specific studies of areas considered for fuel peat development are required. This may result in further delays in realizing the production potential of fuel areas.

Mining - If the topographic restraints are considered to be of prime concern then standard milling or wind-row techniques cannot be used to develop the peat mine. If the peatland cannot be effectively drained (preferably by gravity), vehicle traffic will be restricted.

Since fuel peats occur at depth, the presently proposed 2% slurry hydraulic recovery method appears to potentially be the most effective mining technique but its effectiveness is not yet proven (Tibbetts and Fraser, 1978).

The technology for preparation of peat for firing is now under intense investigation, particularly with respect to wet combustion. The feasibility for gasification of peat for fuel on a production scale has yet to be demonstrated. Either of these techniques, if proven technically and economically feasible, would lead to a re-assessment of the fuel potential of peat resources.

Economics - The economics of both short- and long-term use of peat as an energy source must be investigated. The economics of other potential uses of peat not related to energy must also be considered. Such analyses will provide a more realistic long-term planning evaluation of the potential peat resource in Canada.

5.0 POLICY AND LEGISLATION PERTAINING TO PEAT MINING

The most significant efforts toward development of environmental policy specific to the peat resource appear to have taken place in Minnesota and New Brunswick. In the Minnesota policy paper, the Department of Natural Resources recommended that an environmental assessment work sheet be required for a peat-mining operation which will use 65 ha or more (Minnesota Department of Natural Resources, 1981). Also, an environmental impact assessment is recommended for mining operations occupying 130 ha or more. Drainage of peatlands should be subject to existing water permit rules. The department has promulgated rules for appropriation of state waters associated with peatlands. The policy further recommends that specific mitigation steps be outlined where degradation of the peatlands is anticipated, and that detailed monitoring and reclamation plans be developed prior to approval to develop.

In the development of specific policy pertaining to environmental control of harvesting activities in Minnesota, a number of options were considered. Those which appear to have had most support include: (1) The establishment of drainage regimes and outflow points for each base tract and strict enforcement of drainage requirements, (2) The requirement of regular monitoring of effluents and emissions associated with peat development, and strict enforcement of full compliance with all applicable pollution control rules and regulations (including federal and local regulations).

The New Brunswick Department of the Environment is now assessing the need for specific policy pertaining to protection of the province's wetlands, which include peatlands (Kent-Gillis and Gemmell, 1979). Unless environmental problems are identified which are specific to development of peatlands, it appears that the province will rely on regulations under the Clean Environment Act. Also under the terms of the Quarriable Substances Act, the New Brunswick Department of Natural Resources requires submission of site-specific information prior to granting of mining licences.

Although guidelines have been issued by Environment Canada for the Bishops Falls operation in Newfoundland, regulatory agencies have generally relied on existing environmental control policy or legislation to ensure environmentally sound peat harvesting or mining operations. This includes permitting procedures or preparation of environmental impact assessments, neither of which set out criteria specific to peat operations. Until such time that harvesting of peat becomes more prevalent, development of policy or legislation specific to environmental effects of peat mining is considered unlikely.

The federal government is now considering a proposed amendment to the Income Tax Act Canada by which peat deposits developed for use as a fuel will be treated as a mineral resource. Basically the rationale for this proposed amendment is to provide tax treatment of fuel peat deposit development which is equitable with that for other energy development and encourage development of alternative fuels in Canada in accordance with national energy policy.

6.0 ABSTRACTS AND REFERENCES

6.1 INDEX TO ABSTRACTS

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1. Andrzejewski, M., and D. Rosikiewcz. 1975. Ability of some trace elements to form complexes with humic acid. In: Studies about humus. Transactions of the International Symposium, Humus et Planta VI. Prague, August 18-22, 1975. pp. 107-112.

Complexes of fulvic acids with numerous cations have been described and characterized (SCHNITZER and SKINNER 1963, VAN DYKE 1971). Fulvic acids can react with metals in an acid medium which is not favourable to humic acids and inversely, in a basic medium many cations are not able to react due to precipitation. Although according to CHABEREK and MARTELL (1959) the pH determines the properties of organo-metallic complexes, most reactions of humic acids with metals can be caried out in a pH of about 7. Another factor affecting the properties of these complexes is the ratio of humic substances and metals. SCHNITZER and SKINNER (1963) found that the infrared spectra of the complexes changed as iron was added to fulvic acids. Addition of cations to humic acid solutions is limited due to precipitation, but it was observed (ANDRZEJEWSKI and ROSIKIEWICZ 1974) that numerous cations formed complexes before precipitates were formed. These complexes can be determined on the basis of the variation in optical densities of solutions containing different quantities of metal and the same amount of complexing humic acids.

2. Anonymous. 1981. Minnesota peat program final report. 93 p. Prepared by the Minnesota Department of Natural Resources. Division of Minerals. August 1981.

A summary is presented of five years' work evaluating the environmental, social, and economic consequences resulting from the development of peatlands.

Peatlands are a valuable resource and since our knowledge of it is changing policies for utilization should be kept flexible.

3. Anonymous. 1981. Peat policy formulation - a system approach. 71 p. Prepared for the Minnesota Department of Natural Resources. Minerals Division. April 1981.

Policy formulation can be summarized in three steps.
1. Definitionary problems, shown through the

interactionary constraints, alterables, needs and stabeholder groups.
2. Determining policy objectives by using information from the first step.
3. Determining alternatives for achieving objectives.

4. Anonymous. 1980. Environmental feasibility study of the Jamaica peat resources utilization project. Prepared by Natural Resources Conservation Department Ministry of Mining and Energy and The Traverse Group, Inc., Ann Arbor, Michigan. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. July 22-24, 197. pp. 617-634.

The high quality of peat in the Black River Lower Morass (7090 ha) and the Great Negril Morass (2290 ha) makes it technically feasible to use these peat resources as a source of fuel. Both wetlands contain an estimated total of 240 million metric tons of wet peat, which when dried could be burnt as fuel for an electricity-generating plant. It has been calculated that the quantity available in the two reserves is sufficient to power a generating capacity of 80 MW per year (30% of present Jamaica Public Service capacity) for 30 years.

The project, as proposed, would entail the mechanical excavation and extraction of peat from wetlands and its transport, via barges, to suitable areas of flat land (600-800 ha) for solar drying. When dried the peat would be moved to the site (4 ha) of the power station to be burnt for steam production. The mining of peat would essentially remove the substrate of the wetlands and would gradually create, over the course of the operation, a large lake or system of lakes.

The major economic advantage of the proposal is the saving in foreign exchange that would otherwise be used to import the equivalent amount of fuel oil. Used in this manner, however, peat must be regarded as a non-renewable resource as the rate of extraction would far exceed the rate at which peat can be produced by the wetlands.

5. Anonymous. 1979. Minnesota peat program - legislative status report. Prepared for Minnesota State Legislature, by Minnesota Department of Natural Resources, April, 1979. 148 pp

A status report, summarizing research done up to this time under the Minnesota Peat Program for development of management policy.

Research is focused in four areas; 1) natural environment, 2) socio-economy, 3) utilization options and 4) reclamation studies.

6. Anonymous. 1972. Peat humic materials: a review of the chemistry. Proceedings of the Symposium Peat Moss in Canada, University of Sherbrooke, Sherbrooke, Quebec. April 24-25, 1972. pp. 316-324.

Peats consist largely of plant fibers and polyelectrolyte humic materials. The polyelectrolyte, ion exchange, and metal ion chelation properties of these humic materials probably make important contributions to the surface and sorption properties of peats

It can be speculated that H-bonding, and π-bond complexing, by the aromatic rings also contribute to the sorption properties of peats.

7. Arafat, N.M., and W.A. Glooschenko. 1981. Method for the simultaneous determination of arsenic, aluminum, iron, zinc, chromium, and copper in plant tissue without the use of perchloric acid. Analyst 106: 1174-1178.

A 0.5-g sample of plant tissue was digested with a mixture of concentrated nitric and sulphuric acids (2+1 V/V) and hydrogen peroxide. Arsenic was determined by the hydride generation method. Aluminum, iron, zinc, chromium and copper were determined by direct flame atomic-absorption spectrometry. The detection limits in dry plant material$_1$ using 50 ml of aqueous solutions for analysis were 0.5 ng g^{-1} for arsenic and 0.1μg g^{-1} or aluminum, iron, zinc, chromium and copper. The relative standard deviations were 4, 6, 1, 11, 6 and 7% respectively. All six metals were determined from the same aliquot with recoveries ranging from 93 to 118%. A study was made of the composition of the precipitate that settled out from the extracts. X-ray diffraction revealed the presence of α-aluminum oxide (corundum) and some quartz in the anti-bumping granules. α-Aluminum oxide was a source of contamination for the aluminum analysis.

8. Arafat, N.M., and W.A. Glooschenko. The use of bog vegetation as an indicator of atmospheric deposition of arsenic in Northern Ontario. Environ. Poll. in press.

There is ample evidence of the release of potentially toxic metals from the Sudbury region of Ontario. However, insufficient information is available concerning the distribution of arsenic from atmospheric inputs in northern Ontario. This element is associated with smelting activities in other parts of Canada especially northern Manitoba and Yellowknife, N.W.T. Bog vegetation was chosen as indicator of this chemical input, since bogs receive their chemical inputs solely from atmospheric fallout. This alleviates problems associated with monitoring lake sediments and soils which can receive elemental inputs from their watershed.

An increase in arsenic concentration was found in bog vegetation near smelters, both at Sudbury and in the Timmins/Kirkland Lake, Ontario/Rouyn, Quebec areas. A distinct decrease in concentration occurred with distance. A comparison of arsenic levels between species examined at the same location indicated that the moss and lichen species were more efficient scavengers of arsenic than low shrubs. Concentrations determined in this study were above background data from more remote areas, especially in the Sudbury area where a 20 x increase was noted in lichens. This study further confirms the use of bog vegetation as a sensitive indicator of elemental fallout.

9. Asmussen, D. 1980. The Minnesota peat program. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. Dec. 1-3, 1980. pp. 647-655.

The MDNR Peat Program has been working for nearly five years to fulfill a Minnesota State Legislative mandate to study the state's peat resources, determine development and preservation opportunities, and determine the possible impacts of utilization. Initial planning of the program priorities identified five categories of knowledge required to adequately address legislative concerns:

1. Environmental Baseline Information (including air, water, vegetation, and wildlife);
2. Socio-Economic Information;
3. Studies of Utilization Opportunities and Constraints;
4. Reclamation opportunities following mining; and
5. Inventory of peat resources.

10. Aspinall, F., and W. Hudak. 1980. Peat harvesting - state of the art. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. Dec. 1-3, 1980. pp. 159-173.

Large-scale peat harvesting methods are presently under study by Dravo Engineers and Constructors, a unit of Dravo Corporation, as part of a contract awarded to the Institute of Gas Technology by the Gas Research Institute.

The development of a reliable, efficient, economical, and environmentally acceptable harvesting and reclamation plan is crucial to the success of a peat fueled project. Several harvesting options are available, but no one system is best suited for all bogs. An integrated harvesting plan must be selected that addresses the trade-offs between cost, reliability, and environmental impact. Factors such as bog and peat characteristics, transportation distances, operating and reclamation requirements, and desired final product will determine which production system is best suited for a specific site.

This paper discusses the state of the art of large-scale peat harvesting methods, and briefly describes the equipment required and other factors which impact the extraction of peat for use as an energy source.

11. Atlay, M., A. Ertugrul, and R.F. Sober. 1980. An introduction to environmental considerations of peat developoments, with reference to air and water quality. In: Peat as an Energy Alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia. Dec. 1-3, 1980. pp. 603-616.

The purpose of this paper is to provide a general overview of environmental regulations applicable to a commercial-scale peat extraction and processing operation, and its support facilities. Following the general overview, air and water pollution aspects of peat development are discussed in detail. Interactions between water quality and hydrology are also discussed in detail.

12. Äyräs, M. 1979. Some trace metals in till and humus in the Hannukainen area, Kolari, northern Finland. Geological Survey of Finland, Report of Investigation. No. 44. 34 pp.

The metasediments in the Hannukainen area of Kolari have a skarn horizon that contains several magnetic ore bodies. One of them, the Laurinoja ore body, is copper bearing, and the footwall of another, the Vuopio ore body, contains a low-grade molybdenum mineralization. The thickness of the overburden in the area varies, the maximum being 25 meters.

Till and humus were sampled across the skarn horizon. The till samples were assayed by AAS by applying three different digestion methods; 1) HCl and H_2O_2 cold; HCl (1:100) cold; and 3) HNO_3 hot. The humus samples were asked, then digested in HCl and analysed by AAA. The analytical data were processed into frequency histograms and abundance maps.

The results of the study suggest that the metal anomalies in till are glacigene, but in humus electrochemical. Humus survey seems to be a useful method for pin pointing mineralization in areas with thick overburden and complex till stratigraphy. Till studies in such circumstances are difficult and costly if aimed at detailed information of the underlying bedrock.

13. Bannatyne, B.B. 1964. Preliminary survey of bogs for peat moss in southeastern Manitoba. Department of Mines and Natural Resources, Winnipeg, Manitoba. Publication 63-5. 43 p.

This survey outlines possible commercial deposits of high-quality Sphagnum peat moss in the numerous peat bogs of southeastern Manitoba. The area considered is comprised of townships 1 to 13, ranges 9 to 17 EPM in the southeast corner of Manitoba. Because of the large area of over 4,000 square miles involved, as well as the reconnaissance nature of this survey, the results presented in this report should be considered as being preliminary only. A few deposits have been found that are worthy of more detailed testing; many bogs, containing peat of intermediate to inferior quality, could be eliminated from consideration in any future survey.

14. Bannatyne, B.B. 1980. Sphagnum bogs in southern Manitoba and their identification by remote sensing. Department of Energy and Mines, Winnipeg, Manitoba. 103 p.

This report presents results of a survey of selected bog areas in southern Manitoba to evaluate their potential for commercial development of Sphagnum peat moss, have been identified. The project was carried out under the Canada-Manitoba Mineral Exploration and Development Agreement.

Three bogs in southeastern Manitoba have been developed for commercial production of Sphagnum moss. Between 31,000 and 39,000 tonnes of moss valued at $2,600,000 to $3,700,000 are produced annually.

15. Bascomb, C.L., C.F. Banfield, and R.G.O. Burton. 1977. Characterization of peaty materials from organic soils (Histosols) in England and Wales. Geoderma 19: 131-147.

Eighty-eight samples from a wide range of organic soil profiles (Histosols) were classified as fibric, mesic, or humic using classes defined by field observations of unrubbed and rubbed fibre contents. A second method of classification based on a diagram using laboratory measured rubbed fibre content (RFp) and absorbance (550 nm) of pyrophosphate extract (ABs) was used and the two classifications compared. Pyrophosphate index and 11 other properties of the samples were measured in the laboratory and their class values were studied for the two classifications. Overlap of class values for non-definitive properties was common. Two laboratory techniques for measuring rubber fibre content were compared with a field assessment. A method for measuring water content and extrudability was found to be a promising method for characterizing peat samples.

16. Biomass Energy Institute and Office of Industrial Research (University of Manitoba). 1978. Utilization of wood and other biomass for small-scale electric power generation. Submitted to the Canadian Electrical Association. Oct. 1978. 103 p. and appendix.

A variety of means was assessed to meet the electric needs for 119 identified remote sites from indigenous biomass resources, including peat. Replacement of existing non-renewable energy sources with renewable energy sources was determined not to be economical at this time.

17. Borowiec, J., and S. Baran. 1976. The influence of ecological conditions on the composition and occurrence of microelements in the lowmoor soils of the Lublin region. Proceedings of the 5th International Peat Congress. Poznań, Poland. Sept. 21-25, 1976. Vol. 2. pp. 254-263.

Nine peatland areas were sampled and analysed for concentrations of B, Mn, Pb, Cr, Mo, V, Cu, Zn, Ni, Sr, Ba. Samples came from a wide range of ecological conditions. Several factors were taken into consideration when analysing the results: soil reaction, content of Ca compounds, ecological conditions, water regime, utilization methods and the cultivation state.

It was found that the content of microelements in peat decreased when the acidity of habitat increased.

18. Boyd, C. E. 1978. Chemical composition of wetland plants. In: Freshwater wetlands, ecological processes and management potential. Edited by: R.E. Goods, D.F. Whigham, and R.L. Simpson. Academic Press, New York. 1978. pp. 155-167.

Examination of data on the chemical composition of wetland plants reveals that variation in composition increases in the following order: within-site intraspecific variation, between-site intraspecific variation, and interspecific variation. Furthermore, chemical composition changes as some species mature and variation in chemical composition occurs between different plant structures. No average composition for an individual species or ecological grouping of species based on data from the literature would be reliable. Therefore, actual measurements should be made in studies requiring data on chemical composition. Energy content values are more constant than chemical parameters.

19. Boyle, R.W. 1977. Cupiferous bogs in the Sackville area, New Brunswick, Canada. J. Geochem. Explor. , 8: 495-527.

Two cupiferous bogs in the Sackvile area, N.B., Canada, are described. The organic matter (muck) in these bogs contains 2 to 6% Cu;, derived from cupiferous springs that carry copper in amounts ranging from 0.005 to 1 ppm.

The source of the copper in the springs is unknown, but the metal proably originates from the leaching of cupiferous (Chalcotic) deposits in grils and conglomerates at the base of the Boss Point Formation of Carboniferous (Pennsylvanian) age.

The copper occurs in the muck as copper humate(s), the precise chemical characterization of which is unknown.

Examples of copper bogs related to copper mineralization in many parts of the world are reviewed, and it is pointed out that such bogs are good geochemical indicators of cupiferous deposits.

The moss, Pohlia nutans , grows in the springs in the copper bogs and in other wet sites in the area where large concentrations of copper occur. This moss is tolerant to large amounts of available copper and markedly accumulates the metal. When slightly chlorotic, Pohlia nutans may indicate the presence of higher than normal amounts of copper.

20. Breng, R. 1976. Proteins in humic acids. Proceedings of the 5th International Peat Congress. Poznań, Poland. Sept. 21-25, 1976. Vol. 4. pp. 331-335.

Of the nitrogen released via hydrolyses 20-50% are identified as amino acid nitrogen, 10% are hexosamine nitrogen. The hydrolysis residue contains the remaining nitrogen. On further reaction, nitrogen containing heterocyclic compounds or aromatic amines can result.

The author's results indicate that strong H-linkages, not atomic linkages exist between humic acids and proteins.

21. Brenner, S., R. Ikan, N.A. Agron, and A. Nissenbaum. 1978. Hula Valley peat: review of chemical and geochemical aspects. Soil Sci. 123: 226-232.

In the Hula Valley, Israel, four layers of peat of Middle Pleistocene to Holocene age, interbedded with Limnic clays and marls, are found above 300 m depth. The main detrital materials are kaolinite, montmorillonite, and illite. Average elemental values of organic matter of dry peat are: C, 15-29%;

H, 1.8-3%; N, 0.8-1.2%; S, 2.3-5%. Ash content (dry), 36-59%. The average calorific value ranges from 1670-3400 cal/g. Organic constituents isolated from the upper layer include: C_{12} to C_{26} fatty acids, β-sitosterol, β-sitostanol friedelin and friedelanol, ceryl alcohol, a series of hydrocarbons, among them polycyclic hydrocarbon, perylene, 13 aminoacids and a series of polysaccarides of molecular weight in the range of 40,000.

A detailed quantitative investigation of the distribution with depth in the top peat layer of the humic, fulvic, and hyamatomelanic acids, as well as of the β-humus and humin, showed humus to be the dominant fraction of the organic matter. Its amount increases from 62% of the organic matter (by weight) at the surface to 70-90% at 2 m. The fulvic acid and polysaccharides show rapid decrease with depth, accompanied by concomitant increase in the β-humus. The humic acid increases with depth.

Analyses of the peat organic fractions for carbon and hydrogen stable isotopes shows that with depth the difference in δC^{13} between the humic and fulvic acids disappears and the δC^{13} stabilizes at around -18 ppt. The isotope data indicate the dynamic nature of the fulvic acid in the peat. The δD values were around -60 ppt. but the data are too meager for any firm conclusion

22. Brooks, K.N., and S.R. Predmore. 1978. Final report, phase II - peat program, hydrologic factors of peat harvesting. Minnesota Department of Natural Resource. 36 p.

This report describes the hydrologic characteristics of natural peatlands, methods of peat harvesting, and the expected impacts of peat harvesting on water resources. Lake States, Canadian and European experiences are reviewed and coupled with the characteristics of Minnesota peatlands to estimate harvesting impacts.

23. Brown, J. L., and R. S. Farnham. 1976. The mineral content of peat and the degree of decomposition. Proceedings of the 5th International Peat Congress. Poznań, Poland. Sept. 21-25, 1976. Vol. 2. pp. 247-253.

The relation between the mineral content and degree of decomposition was related to the content of fibres greater than 0.15 mm. A statistical analysis by linear regression showed a better correlation between the peat mineral and fibre contents when the latter were expressed on the weight basis (r^2= 0.61) rather than the volume basis (r^2 =0.33). A better correlation existed (r^2=0.94) between the fraction of peat ash which was soluble in dilute HCl and the content of peat fibres.

24. Bunzl, K., W. Schmidt, and B. Sansoni. 1976. Kinetics of ion exchange in soil organic matter. IV. Adsorption and desorption of Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+} and Ca^{2+} by peat. *Can. J. Soil Sci.* 27: 32-41.

The equilibria as well as the rates of adsorption and desorption of the ions Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+}, and Ca^{2+} by soil organic matter were determined in batch experiments as a function of the amount of metal ions added to an aqueous suspension of HCl-washed peat. Simultaneous determination of the metal ions and hydrogen ions in the solution by atomic adsorption spectrophotometry and pH-measurements showed that the adsorption of one divalent metal ion by peat was coupled with release of two hydrogen ions. Since this equivalent ion-exchange process causes a corresponding increase of the electric conductivity of the solution, the rates of the adsorption and desorption processes were determined by an immersed conductivity electrode.

The distribution coefficients show that the selective order for the metal adsorption by peat is $Pb^{2+} > Cu^{2+} > Cd^{2+} \cong Zn^{2+} > Ca^{2+}$ in the pH range of 3.5 to 4.5. The slope of -2 as observed in a double logarithmic plot of the distribution coefficients versus the total solution concentration confirms the equivalence of the ion-exchange process of divalent metal ions for monovalent H_3O+ -ions in peat. The absolute rates of adsorption, as well as the rates for the fractional attainment of the equilbrium, increasewith increasing amounts of metal ions added. This behaviour is also observed for the subsequent desorption of the metal ions by H_3O^+ -ions. At a given amount of metal ions added, the absolute rates of adsorption decrease in the order $Pb^{2+} > Cu^{2+} > Zn^{2+} > Ca^{2+}$, while order $Ca^{2+} > Zn^{2+} \cong Cd^{2+} > Pb^{2+} > Cu^{2+}$. The half times adsorption and desorption were in the range of 5 to 15 sec.

25. Bysiek, M., R. Oertli, L. Salonen, and J. K. Miettinen. 1972. Combustion of peat as a source of atmospheric Mercury and ^{137}Cs in Finland. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol. 5. pp. 177-184.

Peat samples collected from four major peat fields in Finland were analysed for mercury by two independent methods; the Schoninger oxygen combustion method in combination with Brandenberger flameless atomic absorption and the Kosta neutron activation method. Ash and soot from a large heating station (at Niinisalo) were also analysed. The results of these mercury determinations fell within the range of 12-390 ppb, the average being 127 ppb.

With 100,000 tons of peat combusted in Finland annually, this corresponds to 12.7 kg Hg/y, which is negligible when compared with the amounts produced by other fossil fuels and especially with the amount descending in rainfall. (ca. 30 ton Hg/y)

The combustion of peat was also found to be negligible as a source of artificial radioactivity (based upon ^{137}Cs determination) in the atmosphere.

26. Casagrande, D.J., and C.D. Erchull. 1976. Metals in Okefenokee peat-forming environments: relation to constituents found in coal. Geochim. Cosmochim. 40: 387-393.

Ba, Ca, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb and Zn were studied cores of peat from two major vegetational areas of the Okefenokee Swamp, Georgia. Both total peat and organic fractions were investigated. Except from Hg and Pb, metal concentrations were either higher or equal to Clarke values. The sandy bedrock is not an important contribution to metal concentration found in peat. Levels of metals in a given peat sample were related to plant materials which gave rise to the peat; it does not appear that vegetational environment plays a critical role in determining trace metal distribution, but does play a role in determining the amount of humic or pre-vitunitic constituents that eventually are found in coal.

27. Casagrande, D. J., K. Siefert, C. Berschinski, and N. Sutton. 1977. Sulfur in peat forming systems of the Okefenokee Swamp and Florida Everglades: origins of sulfur in coal. Geochim. Cosmochim . 41:161-167.

Six sulfur forms were investigated in profiles of freshwater and marine derived peat forming systems. Total sulfur levels of 0.1-10% were found, thus indicating a major incorporation of sulfur in the very early stages of coal formation. The quantities of hydrogen sulfide and elemental sulfur observed appear to be indicative of whether marine or freshwater conditions prevailed at the site of deposition. Carbon-bonded sulfur accounted for 70% of the total sulfur in freshwater peat and 50% of the total sulfur in marine peat. Over 15% of the total sulfur was in pyritic combination in the marine environment, while levels of pyrite in the freshwater peats were an order of magnitude lower. An ester-sulfate fraction represented 25% of the total sulfur in both freshwater and marine peats. The levels of sulfur forms in the peat profiles are compared to those observed in living plants and to various coal; levels of pyrite and organic sulfur in the peat are similar to those found by other investigators in freshwater derived and marine derived coals.

28. Chapman, S. B. 1964. The ecology of Coom Rigg Moss. Northumberland - II. The chemistry of peat profiles and the development of the bog system. J. Ecol . 52: 315-321.

Chemical analyses of peat profiles are described. They demonstrate changes in peat composition at the different stages in the bog's development from the minerotrophic conditions under which fen peat was formed to ombrotrophic conditions under which Sphagnum-Eriophorum peat was formed.

The peats of the eastern sector of the bog are shown to have been minerotrophic until a comparatively late stage in the bog's development due to the surrounding topography allowing Phragmites to persist even till the present day.

Increased silica and aluminium in the upper peat layers are discussed in terms of increased deposition brought about the activities of man through deforestatioon and the production of open habitats.

29. Choudhry, G.G. 1981. Humic substances: part 1: structural aspects. Toxicol. Environ. Chem . 4: 209-260.

Humic substances are natural polymeric macromolecules and are widely occuring in aquatic and soil environments. They can be divided into three major classes: fulvic acids, humic acids, and humins. By using degradative and other methods, more than 150 monomeric humic sustances can be obtained. These can be grouped into three main types of compounds: aliphatic, substituted benzenes, and polycyclic aromatic hydrocarbon.

Humic substances behave like three dimensional flexible biopolymeres, which possess holes of varying sizes, but there is no agreement on its structure.

30. Clausen, J.C. 1980. The quality of run off from natural and disturbed peatlands. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 523-532.

The results from the first two years of water quality sampling of the run off from four peatland watersheds is reported. Two of these peatlands are drained, one under cultivation and one being mined, while the other two are undisturbed. Comparisons indicate that the disturbed peatlands had higher concentrations of colour, suspended sediment, acidity, potassium, iron, aluminum, and sodium. For all peatlands, spring minimum values occured for pH, alkalinity, specific conductivity, calcium, magnesium, colour, and nitrogen. Maximum values of suspended sediment occured during spring as expected, the minerotrophic fen run off had higher values for pH, alkalinity, specific conductivity, calcium, and magnesium than did the ombrotrophic bog.

31. Clausen, J.C. 1979. The potential effects of peat mining. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium. Arlington, Virginia, July 22-24, 1979. pp. 201-203.

Critical energy shortages in the U.S. have resulted in a search for alternatives to traditional fossil fuels. One such alternative includes peat as a fuel for both gasification and direct burning. Because peatlands are eventually extremely wet environments, the mining of peat may result in changes in both water quantity and quality. Surface water quality effects of greatest concern are impacts of peak flows, the distribution of flow throughout the year, and total annual flow. The effect of peat mining on the local and/or regional ground water resources is also of concern. Potential impacts of peat mining on water quality involve such parameters as pH, acidity, suspended sediments nitrogen, phosphorous and various metals.

The potential effects of peat mining on water resources vary with a number of factors, including peat type and depth, peatland type (bog or fen), the method of mining, the location of the mining operation in the watershed, and climate.

Generally, peat mining operations that require drainage (milled and sod peat) are likely to reduce peak flows and increase low flows and total annual flow. The net result is that flow is redistributed more evenly throughout the year. Peat mining requiring drainage also has the potential to increase suspended sediment and nutrients in discharge waters.

32. Clausen, J.C., and K. N. Brooks. 1980. The water resources of peatlands. A literature review. Prepared for Minnesota Department of Natural Resources, Minnesota Peat Program. 143 p.

Hydrologic characteristics of peat, the hydrologic cycle of peatlands, and the effects of drainage and timber harvesting are addressed under water quantity. In the second section, water quality of natural peatlands, chemical content of peat, the significance of water quality parameters and the effects of agriculture, forestry and peat mining on water quality are discussed.

Forestry, agricultural and mining of peatlands have the potential to modify both water quality and water quantity of Minnesota's peatland.

33. Clausen, J.C., D.G.Asmussen, and D.Karasov. 1981. Peatland development: impact assessment methods and application. Prepared for Minnesota Department of Natural Resources, Minerals Division, March, 1981. 62 p.

An evaluation of common impact assessment methods identified five basic techniques: ad hoc description, overlay maps, check lists and cause-effect matrices, cross-impact matrices and networks. From first to last, these methods were found to increase in cost and in their demand for specific data. A survey of 50 environmental impact statements revealed that most (40) are ad hoc descriptive and that very few use more rigorous approaches. The descriptive method alone is inadequate for assessing peatland impacts. More sophisticated methods help define subjects where information is lacking.

34. Clausen, J.C., K.N.Brooks, and D.P.Guertin. 1981. The water resources of peatlands - summary of two-year results. Prepared for Minnesota Department of Natural Resources, Minnesota Peat Program. 101 pp.

This report is a summary of two years field work on the water quantity and quality of Minnesota peatlands. The water quantity results include information on water budgets, stormflow, groundwater flow, watertable fluctuations and infiltration. The water quality results include information on the study areas, nutrient loading, mining effects, reclamation effects, downstream assimilation and water quality relationships.

35. Clausen, J.C., J.R.Lewis, K.N.Brooks, and D.P.Guertin. 1980. The quality of water discharged from Minnesota peatlands. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 533-537.

Results from the first year of water quality sampling of the stream flow from 39 Minnesota peatlands indicate that the natural range in water quality is quite broad. Regional water quality trends were not obvious, but the water quality of bogs was quite different from fens. As expected, fen streamflow was higher in pH, specific conductivity, alkalinity, calcium, magnesium, iron, sodium and manganese. Fens were higher in suspended sediment and total nitrogen while bogs were higher in colour, acidity, and mercury. Fens also had a greater range in water quality values than bogs. Peatlands were classified based on six water quality characteristics and classifications agreed well with the watershed characteristics of peat type with pH.

36. Clymo, R.S. 1964. The origin of acidity in Sphagnum bogs. Bryol . 67: 427-431.

In most cases where the pH of Sphagnum bogs has been measured it falls in the range of 4.5-3.3 (0.3-5 milliequivalents/l of H^+) though there are fluctuations in time, and with species and micro-habitat (Pearsall 1941, Pearsall & Lind 1941, Pearsall 1956, Gorham 1956, and Clymo 1963).

In bogs which are entirely dependent on precipitation for their water there seem to be at least four possible sources of H^+; These are:

1. Precipitation,
2. Activity of sulfur-metabolizing bacteria,
3. Secretion by live Sphagnum plants of whole organic acid molecules, and
4. Cation exchange in the walls of Sphagnum plants.

37. Crawford, R.L. 1978. Effects of peat utilization on water quality in Minnesota: final report and recommendations to Minnesota Department of Natural Resources. March 1978.

There is a large volume of scientific literature concerning water chemistry as it relates to waters present in peat bogs. The author has assembled several hundred papers concerned with this topic, covering research carried out between about 1890 and 1977. Unfortunately, there is much redundancy in this literature. Also, only a very small fraction of the total is directly relevant to the task at hand - prediction of water quality effects that might results from extensive mining of peat resources. Main, relevant points gleaned from the literature search are presented.

38. Crisp, D.J. 1966. Input and output of minerals for an area of Pennine moorland: the importance of precipitation, drainage, peat erosion and animals. J. Appl. Ecol. 3: 327-348.

An outline balance sheet for water and the elements sodium, potassium, calcium, phosphorus and nitrogen was constructed for a stream catchment of 83 ha within the Moor House National Nature Reserve. The catchment surface comprised 11-20% eroding peat, 80-85% blanket bog vegetation and a little grassland. The input in precipitation was measured and the outputs in solution in stream water, in eroding peat, as downstream drift of invertebrates and by sale of sheep and wool were estimated.

About 80% of the input water left the catchment via the stream.

Only peat erosion and elements in solution in the stream water were significant sources of output of the five elements. For all five the total output was greater than the input, but for the three metals this may reflect additional input by phosphorus, potassium and nitrogen is unlikely. The outputs of phosphorus (33 kg/year) in solution in the stream water were much less than the inputs, but both elements were lost from the catchment as eroding peat, (phosphorus 37 kg/year and nitrogen 1214 kg/year) in large enough quantities to give a total output greater than the input. The estimated net annual losses of phosphorus and nitrogen in all forms were 0.17-0.40 and 9.48 kg/ha/year respectively.

The net annual loss of phosphorus and nitrogen was large when compared with published estimates of losses by heather burning, but probably represents only a minute percentage of the total nutrient fund in the catchment system.

39. Damman, A.W.H. 1978. Distribution and movement of elements in ombrotrophic peat bogs. Oikos 30: 480-495.

Peat cores from ombrotrophic Scandanavian bogs were analyzed for 12 nutrients, and trace elements. Nitrogen, K, Mg, and P are removed from the well-drained part of the hummocks whereas Ca, Al, Fe, Mn, Pb, and Zn are retained. The zone of water fluctuation shows accumulations of Fe, Al, Zn, and Pb, but all other elements except possibly Ca, are removed to some extent. Below the permanent water table all elements show real loses.

The annual growth of Sphagnum carpets on hummocks contains more K, N, and probably P, than that supplied in the annual precipitation but only 11% of the Na, 28% of the Ca, and 56% of the Mg. Considering the ombrothrophic peat moss as a whole, Na is removed most rapidly, and Mg accumulates to the greatest extent.

The study shows that the distribution of elements in ombrotrophic peat moss as a whole, Na is removed most rapidly, and Mg accumulates to the greatest extent.

The study shows that the distribution of elements in ombrotrophic peat is closely linked in with water table location and fluctuation, that K, N, and probably P, are conserved in Sphagnum capitula , and that many elements are removed to a considerable extent before the peat becomes permanently anaerobic.

40. Dunson, W.A., and Martin, R.R. 1973. Survival of brook trout in a bog-derived acidity gradient. Ecol. 54: 1370-1376.

The acidity in Bear Meadows Bog water (pH 3.7-4.7) is not due to carbonic acid or to any other volatile acid. The approximate pK of the unknown bog water acid(s) is 6.0-6.5. Fish do not occur in Bear Meadows Bog or in Sinking Creek over a 4.8 km section below the bog where water pH is too low for their survival. The lowest pH in which brook trout and white suckers were caught in Sinking Creek was 4.25 at area 5 (5.25 km below the bog) after a period of unusually heavy rainfall. At a different time brook trout alone were caught at area 4, 5.2 km below the bog, when the pH was 4.75. The lowest recorded pH at this site was 4.0. Survival times of hatchery brook trout placed in boxes in Sinking Creek were directly related to pH. Individual differences in tolerance to low pH were quite marked.

41. Ek, J. 1976. Munkajaure: Molybdenum in peat and till. J. Geochem. Explor. 5: 265-270.

Organic samples from peat bogs and from the narrow zones with peat along the stream channels can be successfully used in regional prospecting for molybdenum ores.

42. Ekman, R., and M. Ketola. 1981. Analysis of lipid components in peat from a Finnish Sphagnum bog. Kem. - Kemi. 8: 488-493.

The detailed composition of lipid components in extracts from Sphagnum peat was determined to provide a basis for routine analyses of peat extractives. Glass capillary gas chromatography combined with mass spectrometry of the benzene-soluble extractives from Sphagnum peat allowed the separation and identification of all significant long-chain acids, alcohols and ω-hydroxy acids were the major component groups together with minor amounts of α,ω-dicarboxylic acids, hydrocarbons, sterols and triterpene alcohols.

With quantitative standards added at the extraction stage the amount of different free lipid monomers could be conveniently determined in one run by gas chromatography and mass spectrometry of unfractionated extracts after methylation and silylation. The total amounts of lipid components (free + esterified) were obtained by similar analysis of the saponified extracts. These simplified routines were applied in determinations of lipid components in Sphagnum peat samples of various ages from Karevansuo bog in southwestern Finland. The amounts of lipids analyzable by gas chromatography decreased significantly (from ca. 23 to 12 mg/g dry peat) with increasing age of the peat samples taken at 135-190 cm depth, and remained at a relatively constant level (ca. 12 mg/g) in the samples from 190-270 cm depth of the bog.

The extractives-free peat residues were found to contain hydrolyzable benzene-insoluble polymeric esters composed mainly of the same ω-hydroxy acids as identified in the benzene-soluble extractives.

43. Erametsa, O., K.J. Lounamaa, and M. Haukka. 1969. The vertical distribution of uranium in Finnish peat bogs. Suom. Kemistil. B42: 363-370.

Uranium has a rather high tendancy to escape from the lithosphere into the hydrosphere. It is transported, mainly, in the form of the highly stable uranyl dicarbonate and tricarbonate complexes. It is also known that humic acids form stable complexes with uranium. In this work the capture and the distribution of uranium from ground waters by solid humic acids was studied in 14 arbitrarily chosen peat bogs, scattered in different parts of Finland. It was found that uranium concentration generally peaks to a very sharp maximum at a level beginning one fourth from the bottom of the bog. In every other bog, at the depth mentioned, the uranium content exceeded the detection limit of 30 mg/kg in ash. The method of analysis was by X-ray flourescence, as developed, to detect small amounts of substance. The maximum concentration was found to be 1450 mg/kg uranium in ash. The amount of uranium was evenly distributed over the total bog area. In one bog the distribution of lead and nickel was compared with the distribution of uranium.

44. Eriksson, K., and Eriksson, G. 1976. Hinsen: Heavy metals in peat and till J. Geochem. Explor. 5: 232-235.

Metal content of the bog is anomalous with the highest metal concentrations in the bottom layers close to the till slope. The till anomalies are caused by glacial dispersion and peat anomalies by ground water.

45. Eriksson, K., and Eriksson, G. 1976. Strombo: Heavy metals in peat close to a boulder train. J. Geochem. Explor. 5: 342-344.

Ore boulders in the till have caused anomalous metal contents in the peats as a result of ground water drainage.

46. Ertugrul, A.M., and Sober, R.F. 1979. Effects of peat harvesting and gasification on air quality. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium. Arlington, Virginia, July 22-24, 1979. pp. 173-178.

Major identified potential sources of airborne pollutants from commercial peat harvesting and gasification operations are: peat harvesting, storage, handling, and crushing operations, claus sulfur plant and other process gas vents, flue gas from plant boilers, exhaust emissions from vehicular traffic and heavy machinery, and secondary sources resulting from peat mining and gasification projects. These sources are similar to those expected in coal mining and gasification operations of comparable size.

The major potential air pollutants from the sources listed above are particulate pollutants, sulfur oxides (SO_x), notrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and aldehydes. Among these potential pollutants, particulates, SO_2, NO_2, reactive hydrocarbons, and CO are regulated by the National Ambient Air Quality Standards (NAAQS), as established by the U.S. Environmental Protection Agency (EPA) under the requirements of the Clean Air Act of 1970 (CAA).

An analysis of the design of a peat gasification plant based on the IGT PEAGAS^{tm} Process shows that air pollution control techniques developed for coal gasification plants can limit pollutant emissions to within New Source Performance Standards (NSPS). This is facilitated by the relatively low sulfur content of peat. Computer simulation of air pollutant dispersion from a PEATGAS plant producing 80 x 10^9 Btu/day of SNG shows that Prevention of Significant Deterioration (PSD) requirements for a Class I Area could be met within as close as 10 miles to the plant facility. It is estimated that emissions of fugitive peat dust from a hydraulic peat harvesting operation would be negligible. Various control measures are available to deal with emissions resulting from other types of harvesting techniques as well as associated activities such as storage and handling.

47. Ferda, J., and M. Novak. 1976. The effect of ameliorative measures on the changes of the quality of surface and ground waters in peat soils. Proceedings of the 5th International Peat Congress, Pozan, Poland, September 21-25, 1976. Vol. 5: 118-123.

This work contains a summary of the results obtained in several years' investigation of the effect of the performed drainage and ameliorative liming and fertilization on the changes in the out-flow regime and in the quality of the surface and ground waters in peat soils of the transition type.

The results obtained may be summarized in the following conclusions; in the case of a suitably carried out drainage /spacing of ditches 60-100m/ the outflow regime improves compared with the original, non-drained peat bog. There occurs a distinct increasing of the minimal through flows and the maximum out-flows decrease slightly. In the case of an exceedingly dense network of drainage ditches /below 30m/ the increased minimal through flows are maintained but there exists the danger of excessively high maximum through flows, particularly in the case of a thawing of snow and torrential rain in summer. This danger can be removed to a considerable extent by means of drains, which produce a very favourable effect on the total uniformity of the outflow regime. The quality of the water flowing off from the drained part of the deposit improves compared with the non-drained peat bog.

48. Franciszek, M., and S. Horst. 1976. Effect of the degree of decomposition on changes in the nitrogen fractions and phenols in low peat. Proceedings of the 5th International Peat Congress, Poznan, Poland, September 21-25, 1976. Vol. 2: 306-319.

The investigations on the changes occuring in humic fractions, nitrogen forms and phenolic substances in peat soil were carried out. The peat samples were taken from upper 0-20 cm and below 50 cm from deposits which have been under cultivation (peat bog area - Biebrza).

The microscopic analyses and the contents of humic acids were taken as the index of peat decomposition. The results have proven that degree of peat decomposition has a very marked influence on the contents of humic and fulvic acid and bitumen as well as nitrogen forms and contents of phenols. Highly decomposed peats (from surface layers) contained higher contents of humic and fulvic acids and lower bitumens. The higher amounts of total nitrogen, mineral nitrogen and organic nitrogen were found in the highly decomposed surface layer. On the contrary weakly decomposed peats (mostly deeper layer) and higher ammonium, hexosamine and insoluable humin nitrogen. In investigated peats four phenolic compounds were identified. High decomposed upper layers of peat profiles were richer in phenols than deeper ones.

49. Fraser, D.C. 1961. A syngenetic copper deposit of recent age. Econ. Geol. 56: 951-962.

Copper deposited syngenetically in organic sediments occurs in southeastern New Brunswick, Canada, where a peat swamp contains up to ten per cent copper dry weight. This copper occurrence appears unique in that the metal is contained invisibly in subneutral to slightly alkaline peat. This contrasts sharply with the other copper swamps described in the American geological literature in which megascopic lumps and aggregates of native copper are found in organic sediments of acidic pH.

The source of the copper must be sought in the surrounding ground morainal deposits or in the underlying bedrock. The cupriferous solutions have the characteristics of deeply circulating waters, and enter the swamp as seepages. These water seepages, therefore, are not normal "outcrops" of the water table. The glaciology of the region indicates that the peat could not be more than 4,000 years old, and this maximum age is corroborated by the estimated time required to account for the emplacement of the present tonnage of metal, assuming a constant rate of copper deposition.

50. Fraser, D.C. 1961. Cupiferous peat: embryonic copper ore? The Canadian Mining and Metallurgical Transaction, Volume LXIV, 1961. pp 500-504.

Copper occurs invisibly in a geological environment characterized by swampy conditions and an accumulation of forest peat. This swamp, located in southeastern New Brunswick, contains up to ten per cent copper (dry weight) in the organic sediments. This occurrence appears unique in that the metal is apparently organically combined in a chelate compound. Unike the acidic nature of most peat bogs, the pH of the cupriferous peat is nearly neutral.

Analyses of the peat and associated soils have indicated that the bulk of the copper is contained in the organic sediments. It appears that the copper distribution is affected by capillarity, evaporation and the growth of frost crystals, and that the copper fixation is effected by organic sequestration resulting in the metal being bound to the nitrogen or oxygen components of the forest peat. While such a fixation mechanism is not definitely established as responsible for the immobilization of the metal, the facts at hand are compatible with this preferred hypothesis, which not only accounts for the invisiblity of the copper substance, but also explains its relative restriction to the organic sediments.

The conclusions reached regarding the nature of this swamp environment appear to offer a possible explanation for the genesis of certain indurated bedded copper deposits. It is suggested that the chelation mechanism of copper concentration may have been a factor in the localization of other deposits in the geologic past.

51. Fraser, J.A. 1979. Assessment of peat mining methods considered for proposed Canadian fuel peat operation. In: Management assessment of peat as an energy resource. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, July 22-24, 1979. pp 87-92.

This paper describes alternative peat mining methods considered to meet some of the various conditions encountered on virgin Canadian peatland. These mining techniques are generally based on current peat technology practices on other parts of the world that may be applicable in some of the peat regions of Canada. The technical review of mining methods places particular emphasis on fuel supply for electric power generation. Cost estimates for peat production in operation are outlined. This paper also makes recommendations for steps to be taken in the development of a fuel peat industry in Canada.

52. Furr, A.K., C.L. Schofield, M.C. Grandolfo, R.A. Hofstader, W.H. Gutenmann, L.E. St.John, Jr., and D.J. Lisk. 1979. Element content of mosses as possible indicators of air pollution. *Arch. Environm. Contam. Toxicol.* 8: 335-343.

Since mosses derive their nutrients largely from air, they may serve as possible indicators of the magnitude of air pollution. Samples of *Sphagnum* mosses were collected in the Adirondack region of northeastern New York and analyzed for 46 elements. High concentrations of barium, chromium, iron, lead, molybdenum, titanium and vanadium were found. Concentrations of aluminum and fluorine were correlated and may be related to aluminum and glass smelting activities in the area. The concentrations of a number of other element pairs in the mosses also indicated some correlation.

53. Glaser, P.H., G.A. Wheeler, E. Gorham and H.E. Wright Jr. 1981. The patterned mires of the Red Lake Peatland, northern Minnesota: vegetation, water chemistry and land form. *J. Ecol.* 69: 575-599.

Red Lake Peatland in northern Minnesota covers an area of about 80 x 150 km which is uninterrupted by streams or uplands and consists of a vast patterned complex of raised bogs and water tracks. To the west, a large water track up to 5 km broad carries minerotrophic water from uplands adjacent to the peatland. Three types of fen vegetation occur on strings, flarks and teardrop islands in the water tracks; these fens are characterized by high pH (range 5.2-7.0), high Ca^2 concentration (range 3.0-19.6 mg/1) and High K_{corr}.

(range 23-128 S cm^{-1}).

Raised bogs with radiating lines of spruce trees and "bog drains" form the watershed divides to the east. The bogs are fringed downslope by non-patterned Sphagnum lawns of which incipient water tracks arise. Th major types of vegetation occur on the raised bogs and ovoid islands. They have waters of low pH (range 3.8-4.1), low Ca^{2+} concentration (range 0.5-2.1 mg 1^{-1}) and low conductivity, $K_{corr.}$ (range 12-50 S cm^{-1}).

Poor fens closely resemble bog or fen vegetation, but they may be distinguished by their lcation, water chemistry and the presence or absence of certain indicator species. Poor fens occur on the broad Sphagnum lawns, within ovoid islands that have been altered by fire, and wherever minerotrophic water tracks order ombrotrophic landforms. The poor fens have intermediate ranges in pH (4.0-5.1), Ca^{2+} concentration (2.2-4.3 mg 1^{-1} and K_{corr} (22-50 S cm^{-1}).

The importance of surface drainage in the maintenance of mire patterns is suggested by the localized effects of drainage ditches on the vegetation and landforms. Infra-red aerial photographs and LANDSAT imagery indicate that water flow is channelled across broad surfaces of peat to initiate the development of water tracks, bog drains, and islands that have an ovoid, horseshoe or teardrop shape.

54. Glooschenko, W.A., and J.A. Capobianco. 1982. Trace element content of northern Ontario peat. Environ. Sci. Technol. 16: 187-188.

Peat samples were collected at 0-20 and 20-40 cm depths from several peatland ecosystems located in northern Ontario, Canada. Analysis was made for trace metals Zn, Pb, Cu, Cr, Cd and Hg. Concentration values in general were in the low ppm range and did not significantly differ in terms of peatland type or depth except for Pb. This element was significantly higher in surface peats in bogs and fens. Concentrations of metals in peat found in the study were equivalent to those in U.S. coals suggesting caution during combustion in terms of potential atmospheric input of metals.

55. Gloosechenko, W.A., and J.A. Capobianco. 1978. Metal content of Sphagnum mosses from two northern Canadian bog ecosystems. Water Air Soil Poll. 10:215-220.

Samples of Sphagnum moss were collected from Kinoje Lake, northern Ontario, and Porter Lake, N.W.T. Canada. The samples were analyzed for elements Cd, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Hg, Zn. On a dry-weight basis the concentrations Ca>Mg>>Fe>Mn. The other elements were an order of magnitude or much lower in concentration. In general, concentrations were

Ca>Mg>>Fe>Mn. The other elements were an order of magnitude or much lower in concentration. In general, concentrations were similar to those reported in the literature from Scandinavia.

The two Canadian sites were similar in composition except that the Ontario site was higher in Cd and Pb while the N.W.T. site was higher in Mg and Hg. Differences could be due to a combination of regional geochemical and human activities.

56. Gloosechenko, W.A., J.A. Capobianco, T. Mayer and M. Gregory. A comparison of wet and dry ashing methods for elemental analysis of peat and mosses. Unpublished manuscript. 9 p.

Peat and moss samples were subjected to wet and dry ashing and analyzed for the elements K, Ca, Mg, Cu, Zn, Mn, Fe, and Pb using atomic absorption spectrometry. Wet ashing was found to give somewhat higher analytical results than dry ashing, and lower coefficients of variation.

57. Glooschenko, W.A., J. Capobianco, J. Coburn and V. Glooschenko. 1981. Geochemical distribution of trace metals and organochlorine contaminants of a Lake Ontario shoreline marsh. Water Air Soil Poll. 15 (2) : 197-213.

As part of a water quality study on Rattray Marsh, a suburban marsh located on the Lake Ontario shoreline at Mississauga, Ontario, a sedimentary geochemistry study was initiated. In general, Cu, Zn, Pb and Hg were higher in concentration than in local soils, but lower than Lake Ontario recent sediments. Over the past century, an approximate two fold increase in the sedimentary levels of Cu, Zn, Co, Ca and Ni occurred, while Cd increased nearly 4x and Pb, 8x. No correlation was found between metals and organic carbon and the metals appear to be associated with silts and clays as evidenced by (1) factor analysis of geochemical data, (2) higher concentrations in areas of the marsh subjected to high sediment deposition, and (3) analysis of a susended sediment sample from Sheridan Creek, the main tributary basin of the marsh. Organocholorine contaminants include pp^{1}-DDE, pp^{1}-DDD, PP^{1}-DDT, α-chlordane, PCB, mirex and HCB.

58. Glooschenko, W.A., R. Sims, M. Gregory, and T. Mayer. The use of bog vegetation as a monitor of atmospheric input of metals. Unpublished manuscript. 15p.

Bogs are ombotrophic wetland ecosystems which receive all chemical inputs from atmospheric sources. Thus metal content of vegetation can be used as an index of such atmospheric inputs as has been done by several authors. In the present study, several species of bog vegetation were sampled and analysed for lead, zinc, chromium, copper, cadmium and nickel by atomic adsorption spectrophotometry. The 12 bogs sampled were located between Sudbury and Fraserdale, Ontario, 380 km to the north. In addition, samples were collected 940 km north at Winisk, on the shore of Hudson Bay. In general, Pb, Cr, Cu and possibly Cd were highest in vegetation in the southern part of the study area while Zn showed no clear trend. Plant species also showed differences in their ability to accumulate trace metals.

59. Gorham, E. 1956. On the chemical composition of some waters from the Moor House Nature Reserve. J. Ecol . 44: 377-382.

Analyses for pH, specific conductivity, Ca, Mg, Na, K, Cl, SO_4 and HCO_3, NO_3-N, PO_4-P and SiO_2 are presented from some natural waters in the Moor House Nature Reserve, chiefly from pools on the blanket peats at Bog Hill. Samples were collected during both wet and dry periods.

Certain floristic differnces between British and Swedish bogs fed solely by atmospheric precipitation are examined in relation to differences in the ion concentrations of the bog pools.

60. Gorham, E. 1956. The ionic composition of some bog and fen waters in the English Lake district. J. Ecol. 44:142-152.

Analyses for pH, specific conductivity, calcium, sodium, potassium and bicarbonate have been carried out on twenty-five water samples from bogs and fens in the English Lake District. Their ecological significance is discussed, and some ionic interrelations are examined.

61. Gorham, E., and J.B.Cragg. 1960. The chemical composition of some bog waters from the Falkland Islands. J. Ecol. k 48: 175-181.

Bog waters in the Falkland Islands exhibit unusually high salt concentrations owing to very heavy deposition of sea spray. Their acidity appears due partly to exchange of metal cations in sea spray for hydrogen ions adsorbed on the peat colloids, and partly to oxzidation of hydrogen sulphide generated by peat decomposition. The relatively large amounts of sea salt deposited on the peaty soils of the Falklands, together with the lightness of the rainfall, may perhaps be of some importance in maintaining their grass cover against degeneration and erosion.

62. Gorham, E., and R. H. Hofstetter, 1971. Penetration of bog peats and lake sediments by tritium from atmospheric fallout. Ecol. 52: 898-902.

Tritium in surface bog peats of the Red Lake wetland, northern Minnesota, exhibits about the same concentration as in atmospheric precipitation, which is still appreciably enriched by tritium from nuclear weapon testing. Past input pulses are not preserved in the peat profile, and the pattern of subsurface decline suggests that most of the modern precipitation rich in tritium is removed rapidly by evapotranspiration and by lateral runoff within the top 1.5m of the 3.5m thickness of little decomposed Sphagnum peat at the crest of the raised bog. However, some bomb tritium has penetrated, presumably by molecular diffusion down to the discontinuity layer below the highly permeable Sphagnum peat and the underlying well-decomposed and much less permeable fen peat. In profundal lake sediments of four Minnesota lakes the influence of highly enriched precipitation from the early 1960s has likewise been largely transitory and of major significance only in sediment depths of less than 1 m, although some penetration below that depth has occured, presumably by molecular diffusion.

63. Gorham, E. and W.H.Pearsall, 1956. Acidity, conductivity;, and calcium content of some bog and fen waters in northern Britain. J. Ecol. 44:129-141.

In recent years the chemical analysis of bog and fen waters has provided much information of value in characterizing the different types of wet habitats in Fennoscandia (see for example Kotilainen, 1928; Kivinen, 1935; Witting, 1947, 1948, 1949; Sjors, 1950; Gorham, 1950). A somewhat different approach has been employed by Webb (1947). With the aim of obtaining similar information for bogs and fens in the north of Britain, water samples were collected from various sites in the English Lake District and in Scotland during dry weather in September 1952. Analyses for pH specific conductivity and calcium were carried out as soon as possible after collection.

64. Graham, R.B. 1979. Somepeat moss and peat deposits in selected areas. Districts of Nipissing, Sudbury, Algoma, Thunder Bay and Kenora, Ontario. Geological Survey MDC 19, 132 p.

Canada is the major North American source of horticultural grade peat moss. The use of peat, the humified form of peat moss and peat forming plants, is confined to Europe where it is used as fuel for the generation of electricity, for heating, and to a minor extent for medicinal purposes. Due to increasing costs of conventional energy sources and projections of worldwide shortages, there is growing interest in the possibilities of peat as an alternative energy source.

A program to investigate horticultural peat moss and peat resources adjacent to major transportation routes was carried out during the field sessions of 1975, 1976 and 1977. Twenty-one deposits were examined. The deposits were selected from an air photograph study and vary in area from 93 ha to 2050 ha. The latter lies within an open bog of some 3850 ha.

Total identified peat moss resources of sufficient thickness to permit harvesting are equivalent to 16,244,000 six cubic foot bales. These are divided among seven deposits. The two largest are Deposit 25; Trewartha Township containing a resource of approximately 7,463,000 bales and Deposit 24: Stedman Township containing about 4,000,000 bales.

Total identified fuel peat resources amount to over 160,399,000 m^3 of peat in place representing > 37,883,000 tonnes of peat at 55 percent moisture.

A substantial potential for peat is present in the Lyon Township group of bogs and in the Stedman, Trewartha, Meinzinger Township deposits. In the former there is a resource of 28,700,000 m^3 of peat in place representing some 6,270,000 tonnes of peat at 55 percent moisture. Based on European standards adjusted to Canadian conditions, this is sufficient to supply an 18 to 20 MW plant for 38 years. In the latter group there is a resource in excess of 83,642,000 m^3 of peat in place representing over 20,441,000 tonnes of peat at 55 percent moisture. This is sufficient to supply a 40 to 44 MW plant for over 50 years. Since only 52 percent of the Meinzinger deposit was examined, further investigation would enlarge the estimated peat resources of this group.

Deposit 27: McNevin Township represents a more modest peat resource of > 17,600,000 m^3 of peat representing > 3,907,000 tonnes of peat at 55 percent moisture. This would be sufficient to supply a 10 MW plant for over 50 years.

The results of the investigations will assist in land use and ecological planning and provide assistance in the preparation of an inventory of these resources when required.

65. Graham, R.B. and T.E.Tibbets. 1965. Evaluation of peat moss in some bogs of the Rainy River District, Ontario. Department of Mines and Technical Surveys, Ottawa, Mines Branch, Technical Bulletin TB 65, February 1965, 88 pp.

An evaluation of peat in some bogs of the Rainy River District, Ontario, was carried out over an area extending from Fort Frances west to Rainy River, and from the international boundary north to the 49th degree of latitude. The use of aerial photographs, supplemented by a study of literature on bogs in this area investigated earlier, allowed the authors to select twenty-three bogs for field and laboratory examination. Seventeen of these bogs were assessed from viewpoints of location, access, area, depth, cover, drainage, and nature of the peat material present.

Peat has long been recognized as a source of fuel, but in Canada the abundant supply of other fuels precludes its economic use at present. The main value of bogs today is for horticultural peat moss or for cultivation. The emphasis in this report is based on these two aspects.

Horticultural peat moss of commercial or near commercial quality, in sufficient depth and area to provide at least moderate production, occurs in several bogs that illustrate potential for development based on the other factors mentioned above - location, access, drainage, etc. In approximate order of importance these are as follows: the western portion of the Carpenter Bog; the Polar Bear section of the Pinewood Bog; the Dobie Township Bog; the Burriss Bog; and the Devlin section of the Crozier Bog. These bogs merit further investigation by commercial interests.

Bogs from which horticultural peat moss could probably be produced on a small scale, and which hence also merit consideration, are the Crozier section of the Crozier Bog, the bog in Sections 24 and 25 of Shenstone township, and the Railway Bog.

Bogs whose location, drainage and open areas suggest their adaptability for cultivation (such as market gardening and blueberry or cranberry cultivation) are the Fort Frances Bog and the Big Fork Bog.

66. Hazen, C.B., and R.J. Beeson, 1979. Techniques for the assessment of bog hydrology, harvesting and mitigation of water quality impacts resulting from peat harvesting. In: Management assessment of peat and energy resource. Proceedings of the Gas Technology Symposium, Arlington, Virginia, July 22-29, 1979. pp 219-240.

Large-scale hydraulic peat harvesting will involve control of surface and groundwater flows over large areas. A preliminary water budget indicates that civil works associated with this operation will provide sufficient water for a PEATGAS plant operation.

Peat harvesting techniques, local hydrology, and reclaimed land-use options are so interrelated that a comprehensive plan embracing all three of these areas must be formulated prior to actual development.

In an integrated peat harvesting/water quality/land-use plan, the adoption of a multiple land-use/reclamation concept enables tailoring of the hydrologic response over a wide range, including "duplication" of preharvest conditions.

Although additional field work is necessary, the use of natural processes to mitigate water quantity and quality impacts may greatly reduce the time and energy required to construct civil structures for water quantity and quality control.

The conceptual framework developed in this paper delineates the advantages of combining "dry" and "wet" techniques of peat harvesting. Where applicable, combinations of the primary techniques suggest a more reliable and flexible means for peat harvesting.

To adequately characterize the hydrologic system of a bog area, the concept of the reference watershed was developed. Data obtained by monitoring this reference watershed would provide hydrogeologic boundary conditions necessary for developing a comprehensive peat harvesting/water quality/land-use plan.

Cold weather design and operating conditions must be considered for peat harvesting in the proposed Minnegasco lease area. These considerations will manifest themselves in areas ranging from slurry pipeline protection, through harvested-peat storage and harvesting rates, to spring break-up preparations. Special harvesting, transportation, and seasonal preparations are conceivable using the advantage of frost penetration to provide for surface transportation, ditch preparation, and, perhaps, a variation in backhoe or heat/steam harvesting.

67. Heinselman, M.L. 1970. Landscape evolution, peatland types, and the environment in the Lake Agassiz Peatlands Natural Area, Minnesota. Ecol. Monog. 40: 235-261.

The vegetation and peatland types of the Lake Agassiz Peatlands Natural Area are related to topography, waterflow patterns, water chemistry, and the evolution of the landscape as recorded by peat stratigraphy. Eight peatland types are distinguished: (1) minerotrophic swamp, (2) weakly minerotrophic swamp, (3) string bog and patterned fen, (4) forest island and fen complex, (5) transitional forested bog, (6) semi-ombrotrophic bog, (7) ombotrophic bog (raised bog), and (8) raised bog drain. Consistent differences in pH, Ca, and Mg were found between waters of contrasting peatland types. These differences agree with the division of peatland types by degree of mineral soil water influence (minerotrophy). A general topographic alignment of vegetation and peatland types agrees with the hypothesis of chemical controls. Vegetation types often have sharp boundaries related to changes in water properties, peat surface configuration, and paths of waterflow.

Landscape evolution included five phases: (1) Recession of Lake Agassiz about 11,700 years ago. (2) Organic sedimentation of local basins beginning 11,000 years ago. aquatic peats eventually covered 6% of the substratum. (3) Development of fens, marshes, and carr during the postglacial warm-dry interval, beginning about 8,000 years ago. These peatlands built the sedge peats that now cover 46% of the substratum. Paludification caused water tables to rise, and most water basins were overgrown. (4) Invasion of minerotrophic swamp forests around the perimeter of the peatland and along substratum ridges beginning about 5,000 years ago as the climate cooled and precipitation increased. These forests built the basal forest peats that now cover 48% of the substratum. (5) Capture of part of the watershed by Northeast Brook about 3,100 years ago, which caused a water-table divide and mineral depletion, initiated sphagnum invasion and led to the development of the present ombrotrophic raised bogs. As convexity grew, a sharp vegetation and chemical gradient developed along the limit of mineral soil water. Myrtle Lake rose steadily with paludification and now stands 11.8 feet (3.6 m) above the ridge 1 mile (1.6 km) north of the lake. Water tables rose 10-20 feet (3.0-6.1 m) over much of a 70-square mile (181 kmD2U) area. This history does not agree with early concepts of succession, which postulate a trend toward mesophytism with peat accumulation. The only "direction" here is a possible trend toward landscape diversity.

68. Ivanov, Ch., E. Balabanova-Radonova, D. Rouschev, and N.G. Shervashidze. 1967. On amino acid composition of peat and lignite hydrolysates from Bulgarian deposits. Bulg. acad. na nauk. 20: 803-806.

The selection of the method of hydrolysis and proper purification of the hydrolysates are important for identification of amino acids in solid fuels.

In the present study bitumen was eliminated from peat and brown coal. The fuels were then hydrolyzed and the amino acids extracted to determine which amino acids were present, and whether they were free or bound.

69. Kadner, R. 1972. 2nd Session, Group 4. Peat chemistry and physics. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. 5:66-71.

A brief review of 14 scientific papers entitle in principle to the following statements. (1) Peat as well as sapropels can provide valuable sources of organic raw material for the future. (2) Differences as a result of nature conditions and by the very complicity of the chemnical consistency of peats and sapropels bring the basic research very difficult problems. (3) The structural and subsantial changes of peats and sapropels which take place by natural and by artificially caused processes have been studied recently using modern methods and procedures.

70. Kochenov, A.V. and V.N. Kreshtapova. 1967. Rare and dispersed elements in the peats of the northern part of the Russian platform. Translated from Geokhimiya, 3: 330-340.

More than 70 peat deposits in different regions of the European part of the Soviet Union have been tested for the content of rare and trace elements. The distribution of micro elements in peats over the area shows a regular connection with the composition of the bedrock. Favourable preconditions for the accumulation of rare elements in peats are, a high abundance of these elements in bedrock of the source area as well as a small thickness of unconsolidated sediments.

Such conditions exist on the slopes of a positive platform structures reflected in the relief as local elevation.

In the ranges of the peat deposit the distribution of microelements is related to the characteristics of the hydrology of waters of peat bogs and depends to a very small extent on the botanical composition of the peat.

71. Kong, K., J.Lindsay, and W.B.McGill. 1980. Characterization of stored peat in the Alberta Oil Sands area. Prepared for the Alberta Oil Sands Environmental Research Program by Research Council of Alberta, Soils Division, and Department of Soil Science, University of Alberta. AOSERP Report 91, 116 pp.

The open pit method of oil sands mining involves the stripping of an overburden of peat in much of the mineable area. This surface peat, which is stockpiled, is the only organic material naturally available for rebuilding soil fertility. A peat pile was constructed at Evansburg, Alberta, in 1976 and was monitored as a control for two years. A peat stoage area also existed on the Syncrude Lease near Mildred Lake until early in 1978.

The purpose of this research is to investigate the physical, chemical and biological characteristics of peat in the oil sands area, before, during and after storage, to establish handling and storage methods that ensure optimum quality of material available for reclamation. Peat was studied for its reaction to wetting, drying, freezing, thawing and the addition of nutrients, in both the field and the laboratory. The information and recommendations provided in this report will be of importance for future reclamation plans and materials handling procedures.

72. Korpijaakko, E., and P.E.Pheeney. 1976. Transport of peat sediment by the drainage system from exploited peatlands. Proceedings of the 5th International Peat Congress, Poznan, Poland, September 21-25, 1976. pp. 135-148.

Contains findings of an investigation on the effect that the drainage of a peatland for comercial exploitation might have on an adjacent aquatic environment.

Both the water and the bottom sediments were sampled. The analyses consisted of the measurement of pH, transmittance of light by the water samples, identification of sediment components and the quantity of sediments on the bottom.

The first results indicate that the discharge of waters from the investigated peatlands does not affect the pH values of the receiving streams. There is an indication that the mode and the age of operation have a significance in the transport of sediments, but that it is strongly modified by the length of the discharge channel outside the peatland. Short-term variations due to the spring run-off and an accelerated run-off after heavy rain storms have their own effect, too.

73. Kovalev, V.A., and V.A.Generalova. 1969. Geochemical aspects of the movement of iron in recent peat bogs of Byelorussia. Translated from Geokhimiya. 2: 210-220.

Recent Byelorussian peats are characterized by rather high concentrations of iron in both the peat and peatwaters. Ferrous iron predominates in lowmoor peats, although the total iron content is lower. Physicochemical equilibrium in peats depend to a great extent on microbial activity and seasonal changes. Ferrous hydrate may occur at a metastable phase in lowmoor peat, and is subject to transformation into more stable minerals such as carbonates, phosphates and hydroxides.

74. Kovalev, V.A. and V.A. Generolova. 1967. Interaction of humic and fulvic acids with iron in peat soils. Translated from Sov. Soil Sci. 9: 1261-1268.

The binding of iron by fulvic and humic acids as a function of respective concentrations and pH is studied. The movement of iron through a bog as a result of these considerations is examined. Humic acids possess maximum capacity to bind to iron at pH 6. Fulvic acids show a maximum saturation of iron at pH 7. The highest degree of iron-saturation is shown by humic acids from the cultivated peats and the lowest by the humic acids of the buried peat.

75. Lakatos, B., J. Meisel, G. Mady, P. Vinkler and S. Sipos. 1972. Physical and chemical properties of peat humic acids and their metal complexes. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol 4: pp. 341-353.

Raw humic substances were extracted from lowland peat near Lake Balaton, Hungary. After different purification processes very pure metal-free humic substances/ash cont. < 1% were observed. Specific gravities were measured by picnometry and molecular/micelle/weights by ultracentrifuge. Molecular weight of brown humic acid: ~2000/ pH = 2.7/; and fulvic acid: 640/pH = 2.7/. The total acidity of humic acid was obtained pH-metrically. The cation exchange capacity values of different humic substances were determined by complexometry. finally, the redox potential and redox capacity of humic substances have been studied. Stability constants of metal humates were determined by metal ion-selective membrane electrodes.

The infrared absorption spectra indicated that the ion-exchange capacity was derived mainly from the carboxyl groups. The position of the carboxylate antisymmetric stretching band was characteristic of the individual metal humates.

The EPR spectra of transition metal humates revealed the oxidation state of metals and the type of complex chemical bond. Mossbauer effect measurements of iron humates indicated relatively "rather ionic" metal-carboxylate bonds.

According to the animal intestinal absorption measurements, metal humates proved to be very effective.

76. Largin, I. 1976. Investigation of water compositin of natural and cultivated peat deposits. Proceedings of the 5th International Peat Congress, Poznan, Poland. September 21-25, 1976. Vol. 5: 268-278.

The characteristics and composition of oligotrophic (pH 3.5-5.9) and eutrophic (pH 5.3-7.1) bog waters are noted. One important characteristic is that these waters contain suspended particles and soluable organic substances. The differences between the two types of peatland waters as a result of this and other characteristics are addressed.

77. Largin, I.F., S.E.Priemskaya, A.N.Sventikhovskaya and S.N.Tyuremnov. 1972. Microelements content and distribution in peat deposits. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol. 4: pp. 77-85.

Microelements content and distribution data in peat deposits of various types, located in areas of different geological structure are given.

Composition and total content of the microelements are connected with peat deposit types, peat kinds, geomorphological peat deposit positions and to a considerable extent are determined by nature of the rock surroundings.

The content of "mobile" forms of microelements (in extract in HCL) depend on the pH factor of peat and its degree of decomposition.

A high migration ability of zinc and manganese in peat deposits has been established. Microelements distribution in plan and profile of peat deposits is given in the paper.

78. Levesque, M., H. Morita, M. Schnitzer and S.R. Mathur, 1980. The physical, chemical and morphological features of some Quebec and Ontario peats. Prepared for Research Branch, Agriculture Canada, 70 p.

Five different peat profiles were examined by using a number of physical, chemical, and micromorphological methods that have been used in the past to characterize peats. These methods were complemented by others developed in our laboratories. The analytical results were then compared to evaluate the relative merits or shortcomings of each method for the characterization and differentiation of peats.

79. Lishtvan, I. 1976. New recognition of chemical properties of peat. Proceedings of the 5th International Peat Congress, Poznan, Poland. September 21-25, 1976. Vol. 5: pp. 142-162.

16 papers pertaining to the investigation of the chemical properties of peat are analyzed in this report. Some of the papers contain very valuable material which makes our knowledge of the composition and chemical properties of peat more profound and opens new prospects to practical utilization of peatlands and peat both industrially and as objects of the natural environment protection.

All the papers summarized in this report can be divided into three groups.

The first group includes 5 papers on the chemistry and genesis of peat. Seven papers of the second group investigate the compostion and properties of the inorganic part of peat including its minor elements. The papers of the third group (four papers altogether) are devoted to the investigation of the content of heavy metals in peat bogs with a view to assessing the degree of their pollution and studying the content of individual elements in peat.

80. Livitt, E.A., J.A.Lee and J.H.Tallis. 1979. Lead, zinc and copper analyses of British blanket peat. J. Ecol. 67: 865-891.

Analyses of three heavy metals (lead, zinc and copper) in surface peat layers, dated peat profiles and surface vegetation samples from fifteen British sites are discussed in the context of the movement of heavy metals in the peat system; and the present-day and historical patterns of heavy metal accumulation in humified, slow-growing blanket peat.

The concentrations of heavy metals in the surface peat samples provide a basis for the division of the fifteen sites into two groups - 'low background' and 'high-background' sites - reflecting the current urban/industrial status of the sites. Significant regressions were found of the concentrations of lead and copper in the surface peat layers on the log population of the nearest big town to each site.

Dating schemes for five peat profiles were produced by pollen analysis. Generalized linear dating-plots were obtained by correlating individual pollen features with documentary evidence of tree-planting and agrarian or industrial acitivity. Estimated rates of new peat accumulation varied from 1 cm in 5.5 years to 1 cm in 40 years.

Recent rates of heavy metal deposition were calculated for six sites where the rate of peat accumulation had been estimated from pollen analytical/radiocarbon dating. The deposition rates derived from the peat analyses for lead and copper were similar to those obtained by other workers from conventional deposition gauges. The rates for zinc were very much lower than the published figures, suggesting considerable losses by leaching of this metal from the peat surface.

Variation in the concentrations of heavy metals was examined in three dated peat profiles. The distribution of lead in a 'low-background' profile apparently reflects national trends in production and utilization of lead during the last seven or eight centuries, while well-marked peaks in the lead profiles at two 'high-background' sites are shown to correspond well with the documented history of the fortunes of the local lead mines and smelters. The patterns of zinc and copper were less well-defined.

In surface samples of present-day blanket bog vegetation consisting of *Calluna vulgaris* and *Eriophorum vaginatum* , the concentration of lead was higher in the older, more persistent or decaying plant components, whereas the concentration of zinc was higher in the younger, actively metabolizing organs. In a *Sphagnum papillosum* sample, the distribution of lead was fairly homogenous in different age-segments, but the concentration of zinc was higher in the lower, older segments. It is suggested, therefore, that zinc is more mobile within plants and more susceptible to leaching.

Two neighbouring peat profiles were analysed for macrofossils. . Apparent anomalies in the distribution of zinc were attributed to the differences in the vegetational composition of the profiles.

In a laboratory experiment the greater part of the lead and zinc and one-third of the copper in the peat blocks was removed by leaching for 24 h with a chelating agent (EDTA). Lead and copper were virtually unaffected by leaching with sulphuric and acetic acids, whereas the zinc was substantially leached by the sulphuric but not by the acetic acid. It is concluded that leaching of lead and copper through peat is unlikely, but that zinc in surface peat is susceptible to leaching, especially in areas where the pH of rainwater is lowered by atmospheric pollution. all three metals may become available to plants by the action of chelating agents. The use of blanket peat deposits as pollution monitors is evaluated.

81. Lofton, S.M. 1980. Heterogeneity of ecological factors affecting commercial developoment of selected North American peat deposits. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1-3, 1980. pp. 595-616.

A variety of techniques may be required for commercial development of North American peat deposits due to the heterogeneous nature of the ecosystems in which commercially exploitable peat occurs. This paper outlines some of the salient ecological features observed in various peat extraction operations in the U.S. and Canada.

82. Lofton, S.M. 1979. Peat: ecologically sound resource development. In: Management assessment of peat as an energy resource. Proceedings of the Gas Technology Symposium, Arlington, Virginia, July 22-29, 1979. pp. 189-199.

In today's world, any resource management plan must be viewed in terms of overall system stability. A system is defined as anything that functions as a whole by integration of organized parts. The order of a system, whether it be a single organism or a large peat bog, is based upon and maintained by energy. The ultimate goal in any resource development plan must be maintenance of system stability. Any ecosystem disturbance that results in a situation in which energy input exceeds energy yield is unacceptable in terms of ecologically sound resource management.

Peatlands occur in all portions of the world. Wherever waterlogging creates anaerobic conditions, peat may accumulate due to low-level decomposer activity in organic materials. Because peat occurs in a large variety of ecosystem types, ecologically sound management of these valuable natural resource deposits must employ a variety of methods. Sound management of some peat deposits may be simplly preservation. Local conditions will dictate development practices for other deposits.

A whole-system approach to peat development is recommended. A team consisting of hydrologists, air quality specialists, biologists, geologists, soil scientists, and engineers should be organized to study the peat system, plan the best method or methods of development, and implement plans. Computer modeling and pilot projects are recommended to incorporate available information and add to our understanding of peatland dynamics. A number of techniques are available for successful reclamation of postharvest areas. Many are currently being tested in a variety of research projects in the United States, Canada, and Europe.

Using the best available technology, ecologically sound development of selected peat resources appears promising if proper team effort is employed throughout the project.

83. Lopotko, M.Z., G.A.Evdokimova and F.A.Puntus. 1980. Sapropels in Byelorussia: Their types and possible applications. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 597-599.

The resources, compositions and applications of sapropels found in open water basins and under peat deposits were studied.

Group and elementary composition (C, H, N, S) of the organic matter was determined and hydrocarbon complex, chemical nature of humic acids and nitrogen/sulphur compounds in the deposits of different genetic types were studied.

A study was also made of the mineral fraction including microelements.

Physical, thermophysical, rheological, agrochemical, sanitary-biological and other properties of lake deposits were studied.

84. Malmer, N. and H. Sjörs. 1955. Some determinations of elementary constituents in mire plants and peat. Bot. Not. 108: 46-80.

Samples of mire plants (shoots or leaves, roots in one species) and a few peat samples were analysed for most of the following constituents: total ash, "excess base" of ash, Na, K, Mg, Ca, Mn, Fe, SiO_2, P, S, and N. Methods of sampling and analysis are described. Variation between species, relation to plant communities, and influence of some environmental conditions are briefly discussed.

Menyanthes is rather rich in Na, but does not accumulate much silica. The *Cyperaceae* accumulate silica only in less acid environments, and in large quantities in a weakly alkaline environment (Table 3). Rather high values for K and particularly for Mn may sometimes occur in mire plants. Percentages of Ca, Si, and possibly K show a relation tothe bog - poor fen - rich fen series of Du Rietz, and Fe and Mn are usually higher in fens than in ombrotrophic bogs.

The need for productivity studies is emphasized. A few cases of unusually high production are due to submergence of the substrate (all nutrients high in the plant) or to influence of moving water (potassium and sometimes calcium values raised, nitrogen and phosphorus remain low). In "normal" sites the plants seem to be more or less under-nourished, probable frequently with respect to more than one of the elements K, P and N, but compete successfully in this state. Thus the problem of tolerance, reflected in establishment of floristic plant communities, may be different from that of growth and production, and different sets of factors are probably decisive.

Our peat analyses indicate that a bog differs from a fen in H - K - Ca - Mg proportions as well as in lower peat pH and lower content of several mineral substances. Most of these are highly concentrated in the absorbed form on the peat, in comparison with the mire water. A considerable part of the total K in a mire is accumulated in the living plants. Attention is drawn to the significance of micro-biological metabolism, and to the importance of analysing plants as well as peat and water.

85. Mathur, S.P. and R.B.Sanderson. 1980. Relationships between copper contents, rates of biodegradation and degradative enzyme activities of some cultivated organic soils in Ontario, Canada. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 628-632.

This study was specifically aimed at determining whether the inactivation of degradative soil enzymes and consequent retardation of the excessive bio-chemical oxidation of organic soils by additions of Cu at moderately higher than recommended fertilizer rates which were observed in eastern Canadian soils may also occur in some other soils.

The enzyme activities correlated positively with soil respiration indicating the pivotal role enzymes play in biochemical oxidation of the soils. The Cu content in the Keswick Marsh samples varied from 16 to 90 ppm and the Holland Marsh from 70 to 500 ppm. No Cu was added to the soil for this study. The soil C measured was mostly the residue of regular Cu fertilizer additions.

86. Mathur, S.P., and R.B.Sanderson. 1978. Relationships between copper contents, rates of soil respiration and phosphatase activities of some histosols in an areas of southwestern Quebec in the summer and the fall. Can. J. Soil Sci. 58:125-134.

Samples from 17 fields of organic soils (Histosols) were collected on the same day between rows of crops in the summer of 1976 from the environs of Ste. Clothilde, Quebec. Thirty-three properties of the soils were examined for possible correlations. The copper contents of the samples were found to have statistically significant negative correlations with their rates of respiration which were measured as carbon lost as CO_2 upon incubation at 21±2 °C. The acid phosphatatase enzyme contents in these Histosol samples at each of three different levels of soil biochemical activity were also similarly negatively correlated with their copper concentrations. The above results were confirmed almost without exception by the data obtained by similar analysis of seven samples collected from the same area in the fall of 1976 when the fields were bare. The results supported an earlier suggestion of Mathur and Rayment (1977) that copper application (at a few quintals/ha) be investigated as a means of mitigating the mineralization and subsidence of some organic soils. Apparently, the added Cu may inactivate some of the exocellular soil enzymes which normally contribute to the degredation and mineralization or organic matter.

87. McLagan, G.P., A.A.Husseiny, A. Rader, and R.L.Hagenson. 1980. A value impact approach to the assessment of peat utilization in Minnesota.Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 272-276.

Scenarios are developed for peat utilization in the state of Minnesota to provide a realistic economic analysis and assess means to reduce the cost of peat-gas in the area. Parametric analysis are used to minimize the cost of the product, taking into consideration all industrial processes from mining and milling to delivery including land reclamation and ancillary facilities.

Several options are incorporated into the scenarios, including variations in mining, harvesting and dewaering techniques, storage and transportation modes, and utilization processes. k Emphasis is site-specific for the Minesota peat environment.

Value impact studies are conducted for each scenario applying cost/benefit analysis of available options including direct and in-direct costs. Provisions are made for opportunity costs and the impact of peat utilization on other energy resources. Shadow pricing is used to evaluate intangible costs and benefits.

Value engineering approaches are used to seek means for cost reductions in the peat-gas processes and for maximization of benefits from peat utlization in Minnesota. these studies seek to maximize dollar value while providing essential functions at minimum costs.

The case study of Minnesota is unique in the availability of ample peat resources and the lack of other energy sources. Also, several appropriate sites for peat gasification are availble in the state where water is plentiful and industrial and agricultural developments exist in harmony.

88. Mills, G.F., L.A.Hopkins, and R.E.Smith. 1977. Organic soils of the Ruisseau River Watershed in Manitoba. Inventory assessment for agriculture. Canada Department of Agriculture. Monograph No. 17, 70p.

The extensive organic soil areas in the Roseau River watershed occur in seven main peatlands. The study of these peatlands shows that a wide range of ecological conditions exists, but that there is a reasonably good relationship between the three main components, organic landform, vegetation and soil type. In describing the peatland areas of the watershed, information on organic landforms and vegetation types were combined with the soil data and integrated on one map and legend. The range of ecological conditions in the peatlands includes 15 organic landforms, 11 vegetation types, 29 organic soil series and 12 associated poorly drained mineral soils.

In general, the organic soils comprise only moderate depths of organic materials (1 to 2 m), local areas of fairly shallow organic deposits (0.5 to 1 m), and other areas of deeper organic soils (2 to 5 m). The dominant organic soils are Terric and Typic Mesisols developed on moderately well decomposed peat underlain by lacustrine sediments. These mineral substrates range in texture from sand to clay; clayey and loamy deposits are dominant. Fen peat and forest peat are the most common surface organic materials in the watershed, followed by forest-fen peat and sphagnum peat.

Most of the organc soils are very poorly drained, and in their natural state, they become flooded in the spring and during heavy rainfalls. The peatlands in the watershed serve as catchment basins for runoff from adjacent uplands. In this manner, the peatlands are an important part of hydrology of the watershed because they provide a year-round reservoir for water. The organic soils in the eastern half of the watershed are commonly covered with black spruce and tamarack and include local areas of cedar, balsam fir, and shrubs such as willows and swamp or dwarf birch.

Each organic soil in the watershed has been classified according to its potential capability for agricultural use after reclamation. Classification is based on characteristics that most often affect the agricultural capability and development difficulty or organic soils. In general, the agricultural capability is low because difficulties of water control will probably continue to limit the use of most soils, and because many of the soils formed on forest peat have a high wood content. About 10% of the organic soils have good agricultural potential, about 80% have fair potential, and 10% have almost no potential. The development difficulty ratings of the organic soils indicate the relative degree of dfficulty in reclaiming these soil areas for agriculture. The ratings, based mainly on the probable amount of reclamation needed for suitable water control, show that most areas require large reclamation projects.

89. Moneco Ontario Limited. 1981. Evaluation of the potential of peat in Ontario. Ontario Ministry of Natural Resources, Mineral Resources Branch. Occasional Paper No. 7, 193 p.

An overall review of the possible uses and the opportunities for development of the peat resource in Ontario. The peat resources of Ontario were assessed. The following areas were considered, peat mining, peat processes, potential applications of peat in Ontario, environmental considerations, regulatory guidelines.

90. Morita, H. 1981. Changes in phenolic composition of a peat soil due to cultivation. Soil Sci. 131: 30-33.

During the first 5 years of cultivation, a peat soil undergoes selective changes in the chemical composition of soluable phenolics. Of the 18 phenolics analyzed, compounds such as substituted hydroxycinnamic oxides and 4 hydrozxybenzoic acids appear to diminish more rapidly than 3, 4 dihydroxy-benzoic acid and 4 -hydroxy - 3-methobenzoic acids. It is suggested that phenolic compounds may be useful markers with which to follow the decomposition process in cultivated peat soils.

91. Morita, H. 1980. Peat and its organic chemistry. J. Chem. Ed. 57:695-696.

Despite its potoential commercial importance and wide-spread occurrence, peat has not attained the status of a legitimate natural product worthy of serious study by chemists (supported by NSF). Nor is the subject dealt with in chemistry textbooks. This article describes briefly what peat is and what role chemistry plays in its use.

92. Morita, H. 1980. Peat as a future source of organic raw materias. Chem. Can. 32: 18-19.

The organic products resulting from the pyrolyses of peat and their importance as an organic intermediate in industry are discussed. The products of peat tar; hydrocarbons, phenols, nitrogen basis, other chemical intermediates and peat bitumen are addressed specifically.

93. Morita, H. 1980. Total phenolic content in the pyrosphosphate extracts of two peat soil profiles. Can. J. Soil Sci. 60:291-297.

The Folin-Ciocalteau reagent was used to determine the total content of soluable peat phenolic compounds by a colorimetric method. The response of known phenolic compounds to the reagent was measured and it indicated its usefulness for studying peat humus. the results showed that the absorbance at 550 nm of the $Na_4P_2O_7$ extracts of peat materials from two peat soil profiles was correlated with the total phenolic content but anomalous results were encountered in some horizons. Additionally, the total phenolic content per microgram of dissolved organic matter and the behaviour of known phenolic compounds revealed that one peat profile had the most reactive phenolics in the bottom horizon.

94. Morita, H. 1975. Polyphenols in the lime water extractives of peat. Soil Sci. 120: 112-116.

From the lime water extractive of a peat soil a variety of phenolic compounds have been isolated. The identity of the compounds has been established by chromatographic and spectroscopic techniques. It is suggested that, when peat is treated with lime, certain phenolic compounds become solubilized as calcium complexes and that the removal of these compounds aids the decomposition of the peat.

95. Morita, H. 1968. Polyphenols in the extractives of an organic soil. Proceedings of the 3rd International Peat Congress, Quebec, Canada, August 18-23, 1968. pp. 28-31.

The simpler phenolic compounds occuring in plants are briefly reviewed. Methods for the analyses of the phenolic moieties in plant extracts are cited. Some of the established methods of analyses have been applied to the hot water, pyrophosphate, benzene/alcohol and acetone extractives of a peat soil. The results indicate the presence of a variety of known plant phenolic compounds in the soil of which p-coumaric acid and ferulic acid are the most prominent ones. The simple phenolic moieties in Sphagnum have also been examined.

96. Naucke, W., H.V.Laaser, and F. Tarkmann. 1972. New chemical investigations on water-soluable organic substances in low-decomposed Sphagnum - peats. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol. 4: pp. 45-60.

Humic substances of peat are studied using different methods. It was found that the pretreatment and treatment of peat samples as well as the kind of peat analyzed are factors which determine the occurance of certain groups of humic substances.

97. Nissenbaum, A. 1974. Deuterium content of humic acids from marine and non-marine environments. Mar. Chem. , 2:59-63.

Deutrium values obtained for humic acids isolated from marine sediments from the N.E.Pacific area in the range of δD = (-105±5‰) corresponding to values obtained for marine plankton from the same area. Soil humic acids have a much broader range of δD values (-57 to -97‰) depending on the isotopic values of the precipitation and the isotopic composition of the parent plant precursor.

Data obtained on hydrogen isotope distribution confirms previous hypothesis based on chemical analysis and on carbon isotopes, which indicated the authigenic nature of marine humate.

98. Oldfield, F., P.G.Appleby, R.S.Cambray, J.O.Eakins, K.E.Barber, R.W.Battarbee, S.R.Pearson and J.M.Williams. 1979. Pb. Cs and Pu profiles in ombrotrophic peat. Oikos 33: 40-45kk.

^{210}Pb, ^{137}Cs, and ^{239}Pu determinations from recent ombrotrophic peat profiles from two sites, Lough Fea Bog, Co. Tyrone, N. Ireland and Bolton Fell Moss. Cumbria, England are reported and discussed. ^{137}Cs profiles reflect both active uptake by contemporary living plants and downward diffusion in the peat. They therefore appear to be affected by sub-lateral and therefore possibly downward mobility of unsupported ^{210}Pb in the peat. They appear to underestimate true age in at least one of the profiles analysed. The ^{210}Pb derived dates appear to come closest to conforming with independant estimates of age based on pollen-analytical evdence, in the more waterlogged micro-environments on a mire surface, though the full effects on the mobility of unsupported ^{210}Pb or regional climate, bog, hydrology and peat compaction and humification remain to be evaluated. Comparison of ^{239}Pu and ^{210}Pb derived dates for near surface peat suggest that the clear sub-surface peat in the concentration of fall-out plutonium may pre-date the true 1963 level in the peat.

99. Pakarinen, P. 1981. Anaerobic peat as a nutrient sink in raised bogs. Suo 32: 15-19.

Four southern Finnish bogs are studied and their chemical analyses are presented.

Ranking of elemental concentrations indicates that among the "trace metals", iron shows a greater mean concentration in deep ombrotrophic peat layers than the "macronutrients". The mean of past peat accumulation is approximately 1/4 of the current mean annual production of Sphagnum fuscum in the same area.

100. Pakarinen, P. 1978. Distribution of heavy metals in the Sphagnum layer of bog hummocks and hollows. Ann-Bot. Fennic . 14:287-292.

Five metals (Pb, Cu, Zn, Fe, Mn) were studied in moss samples collected from ombrotrophic sites in southern Finnish raised bogs. The manganese, lead and iron concentrations (ppm) were higher in the hummock species Sphagnum fuscum (Schimp.) Klinggr. than in the hollow species S. balticum (Russow) C. Jens. and S. magus (Russow) C. Jens. In all the vertical profiles, Pb, Zn, and Fe increased with depth (from living to dead moss). In the hummocks, Mn showed a regular decrease with depth (0-7 cm), while in the hollows no vertical Mn gradient was observed. Compared with northern Finnish material, S. fuscum samples from southern Finland showed elevated concentrations of Fe, Pb, Cu, and Zn.

101. Pakarinen, P. and K. Tolonen. 1977. Distribution of lead in Sphagnum fuscum profiles in Finland. Oikos . 28: 69-73.

Peat and moss material for this study was derived from the mires. The green portion of k Sphagnum fuscum (Schimp.) Klingrr. usually has lower contents of lead than dead moss of a few years ago. This observation suggests that the moss is not actively taking up lead from the organic substrate. In peat profiles studied, a distinct enrichment horizon of lead was found at a depth of 20 to 50 cm which fact demonstrates that some leaching from surface moss has taken place. However, the rate of leaching seems to be low, because the regional pattern of lead in Sphagnum remains clear. In dead Sphagnum fuscum covered by a thin layer of Mylia anomala (Hook.) Gray, two maxima of lead were present: one at surface 0-2 cm and the second deeper in peat.

102. Pakarinen, P. and K. Tolonen. 1976. Regional survey of heavy metals in peat mosses (Sphagnum). Ambio. 5:38-40.

Bryophytes are known to be good indicators of heavy metal deposition from the atmosphere. For some moss species growing in drier habitats in Scandinavia, the distribution pattern of the contents of several heavy metals is related to air pollution, but little work has so far been done on peat mosses. This report gives results of analyses of ten heavy metals in *Sphagnum* samples collected in 15 sites in Finland and in two sites in western continental Canada.

In the whole material, the minimum contents of lead, nickel, chromium and iron were found in an isolated Canadian bog near Great Slave Lake. Higher values of these elements were observed in a sample taken near more populated areas of Alberta, as well as in the Finnish material. In Finland especially lead and also cadmium show higher levels towards the south, while the maximum concentrations have been reported in the literature for *Sphagnum* samples from the south of Sweden.

Thus it appears that peat mosses can be used to reveal regional distribution of heavy metal pollution, even on a global scale. However, differences in moss productivity and in the vertical distribution of metals in the moss-layer have to be taken into account, when accurate estimates of the annual deposition rates are calculated.

103. Pakarinen, P. and K. Tolonen. 1976. Studies on the heavy metal content of ombrotrophic *Sphagnum* species. Proceedings of the 5th International Peat Congress, Poznań, Poland. September 21-25, 1976. Vol. 2: pp. 264-275.

The paper deals with the use of ombrotrophic peat mosses in regional mapping of heavy metal pollution and in monitoring the deposition rates from the air (mg m^{-2} yr^{-1}).

In a road-side transect studied, the contents of Fe, Pb and Cr in *Sphagnum fuscum* decreased with the distance from the highway, but the bog water analyses of the same elements did not show a similar pattern.

In Finnish *Sphagnum fuscum* specimens, the contents of Pb, Fe, Zn and Ni were significantly higher but the content of Mn lower in South vs. North Finnish samples. In ombrotrophic Sphagna from NW Germany and S Sweden, the contents of Pb, Zn and Cu were higher than in South Finland, but the levels of Fe, Mn, Cr and Ni were approximately of the same magnitude. Globally the minimum concentrations of Pb, Ni, Cr and Fe appeared in northern Canadian specimens.

An estimate of the heavy metal fallout in southern Finland was made by determining the biomass production and the metal concentration of the past two years increment of *Sphagnum.* The agreement of *Sphagnum* analysis with the results from a chemical monitoring station was reasonably good for other metals except Mn. Obviously moss analysis offers a cheaper alternative for the regional monitoring of heavy metals.

104. Pakarinen, P., K. Tolonen, and J. Soveri. 1980. Distribution of trace metals and sulfur in the surface peat of Finnish raised bogs. Proceedings of the 6th International Peat Congress, Duluth, Minnesota,

August 17-23, 1980. pp. 645-648.

Representative profiles are presented on the vertical distributions of some heavy (trace) metals and sulfur in *Sphagnum* peat of southern Finnish ombrotrophic bogs. Mn and Cu show maximum concentrations at the bog surface and concentrations decrease with depth. In the profiles studied, Zn, Fe and S have distinct concentration peaks (enrichment layers) 20-60 cm below the surface indicating mobility of these elements in *Sphagnum* peat.

The 0-10 cm layer of hummock *(S. fuscum)* peat of four bogs was dated with moss-increment method and the annual accumulation (retention) rates of elements were calculated. Comparison to snow analyses in the same area suggests that Mn and Fe are concentrated by surface peat, while other elements are more enriched in the snowpack. Further studies (both snow analyses and sampling of total deposition with gauges) would be needed to clarify the selective retention of elements by surface peat.

105. Pheeney, P.E., and N.W.Radforth. 1972. Organochloride residues of New Brunswick muskeg areas. Proceedings of the 4th International Peat Congress, Otaniemi, Finland, June 25-30, 1972. pp. 203-218.

This paper discusses the fate of chlorinated insectides witin a muskeg environment. The compounds located (DDT, TDE, DDE) are identified with reference to depth below the surface.

The procedure of extraction is discussed in detail to illustrate the importance of retaining the maximum amount of waxy material of the peat.

The influence of ponds in muskeg is also discussed to show the effect of water in the accumulation process. This work involves qualitative data obtained with Thin Layer Chromatography, with accompanying extrapolated quantitative results.

106. Predmore, S.R. and K.N. Brooks. 1980. Predicting peat mining impacts on water resources - a modelling approach. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 655-660.

A modelling approach is presented as a practical means of evaluating the hydraulic effects of proposed large-scale peat-mining operations in Minnesota. A deterministic, continuous simultation model is developed to predict water yield and stormflow from undisturbed and mined peatlands. Physically-based relationships are used to simulate runoff from rainfall and snowmelt. Interception, infiltration, percolation, evapotranspiration, overland flow, and subsurface flow are components of the land-phase subroutine. Channel routing is performed by the kinimatic method. A strategy is proposed for model verification and for prediction of hydrologic changes due to mining. For processes where uncertainty exists, the sensitivity of the model is to be evaluated by varying mathematical representations over a range of values considered to be reasonable. A response matrix of peak flows, low flows, and stormflow volumes associated with a range of climatic conditions and mining methods will be developed.

107. Ranta, J.E., E.Ekman, and D.Asplund. 1980. Simultaneous thermal analysis of peat and its extracts. Proceedings of the 6th International Peat Congress, Duluth, Minnesota, August 17-23, 1980. pp. 670-675.

In the study under review thermal analysis is used to characterize peat and its extracts. Samples were investigated using a Netsch STA 429 apparatus and the methods used were TG (thermal gravimetry), DTG (derivate thermal gravimetry), DTA (differential thermal analysis), and EGA (evolved gas analysis). The sample weight was 15 mg and the temperature range 50-800° C programmed at a rate of 5-10°C/min in air. The peat was classified into components according to Lishtvan & Korol, and hence TG, ETG, DTA and EGA curves were obtained for peat bitumen, readily hydrolyzable materials, humic acids and peat cellulose, in addition to those for the original peat sample.

108. R. Bruce Graham and Associates Ltd. 1974. Peat Moss Resources and some associated trace elements, Prince Edward Island. March 24, 1974. 159 p.

Twenty-five peat moss deposits were located through the study of air photos of P.E.I. Sixteen were examined and nine were found to have appreciable amounts of horticulture grade moss.

Trace element determinations were carried out on selected samples from most of the deposits for copper, zinc, lead, manganese and uranium.

109. Richardson, C.J., D.L.Tilton, J.A.Kadlec, J.P.M.Chamie and W.A.Wentz. 1978. Nutrient dynamics of northern wetland ecosystems. In: Freshwater wetlands, ecological processes and management potential, edited by: R.E.Good, D.F.Whigham and R.L.Simpson. Academic Press, New York. pp. 217-241.

Nutrient information was reviewed by compartment (i.e. soils, plants, water and at the ecosystem level among 4 northern wetland types: fens, bogs, swamps, and marshes. Total soil N, P and Ca were lowest in bog peats but the Mg content did not vary appreciablly among wetland types. Cation exchange capacity was > 100meq/100 g for all wetlands. Concentrations of N, P, Ca and Mg were significantly lower in bog plants than fen plants. Seasonal patterns of nutrient concentrations (N and P) in leaves and stems decreased through the growing season in fen plants. Translocation of nutrients from plant parts prior to abscission did not occur in the plants studied. Minerotrophic fen water chemistry differed from that of ombrotrophic bogs in that fen waters were dominated by Ca^{++} and HCO_3^- ions and bog waters were dominated by H^+ and SO_4^{++} ions (Moore and Bellamy, 1974). Seasonal variations in NH_4-N, NO_3-N and PO_4-P were closely related to peatland hydrology, organism uptake and peat exchange characteristics. A cycling study for a central Michigan fen revealed the > 97% of the N, P and Ca was in the peat compartment. The turnover time for N in above ground biomass was approximately 2 years. An examination of plant uptake rates of N and P in the Michigan fen revealed that low plant productivity may be related to low N and P availability. Nutrient outputs for wetland ecosystems, when compared to yields from terrestrial forest systems, indicate that natural outputs for some wetland types are well within the range, or in some cases exceed, outputs from upland terrestrial ecosystems. The capacity of acid peatlands to store or assimilate additional P or K on a long-term basis appears limited. Nutrient dynamics in wetlands at the organism, community and ecosystem level are all poorly understood and are deserving of further study.

110. Risi, J., C. Brunette, R. Cloutier, and H. Girard. 1958. A Chemical Study of the peats of Quebec. Department of Mines, Quebec. Publication No. 350; 32p.

Seveny-three specimens of peat, thirty collected from St. Hyacinthe peat bog and forty-three from St. Blaise peat bog, were chemically fractionated according to S.W. Souci's method slightly modified by the authors.

The relative amounts of bitumen, cellulose, hemicelluloses, lignin, humic substances soluble in hot water, in 2 percent hydrochloric acid (except the hemicelluloses) and in 80 percent sulphuric acid, and total ash, were studied as a function of depth.

Although the relationship between chemical composition and depth is frequently inconsistent, it is nevertheless possible to define a few general tendencies. Thus, in St. Hyacinthe peat bog, the content of bitumen, cellulose and hemicelluloses generally decreases with depth, whereas the content of humic substances increases at first, until a stronger mineralization at the bottom of the bog produces a reverse effect. As to the content of lignin, and of substances soluble in hot water, in 2 percent hydrochloric acid (except hemicelluloses) and in 80 percent sulphuric acid (except cellulose), the corresponding curves are more or less irregular and do not suggest any characteristic relationship with depth. In St. Blaise peat bog, similar tendencies may be noticed, despite more pronounced irregularities in the case of cellulose and hemicelluloses. The peat is well humified in both peat bogs, particularly in the central region (Station F) of St. Hyacinthe bog and in the northern parts (Station C) of St. Blaise bog. The southern part (Station D) of St. Blaise bog is especially remarkable for its high content of bitumen (waxes and resins).

Certain chemical complexes as made evident by analytical fractionation may be considered as a potential source of raw materials for the chemical industry. Thus, from the two peat bogs studied, it would be possible to obtain, through extraction by suitable solvents, the following amounts of chemical complexes. These could then be used in the production of several products of fundamental importance to Canadian industry.

111. Risi, J.C., C.E.Brunette, and H. Girard. 1954. A chemical study of the peats of Quebec. Department of Mines, Quebec, Publication No. 301: 28p.

Twenty-six samples and thirty-three samples of peat taken respectively from the Small and Large Tea Field peat bogs, Huntingdon County, were chemically fractionated according to S.W. Souci's method as slightly modified by the authors.

The amount of bitumen, cellulose, hemicelluloses, lignin, humic substances, substances soluble in hot water, in 2% hydrochloric acid (except hemicelluloses), and in 80% sulfuric acid (except cellulose) as well as the ash insoluble in 80% sulfuric acid and the total ash were studied in relation to depth.

In general, the bitumen diminishes as a function of depth; this is in agreement with observations made in the case of other well humified bogs. The profile for humic substances is, on the other hand, abnormal. Instead of increasing with depth, it indicates, in the instance of the Large Tea Field bog, the presence of an intermediary layer of slightly decomposed peat between two very humified layers, at the bottom and at the surface. In the case of the Small Tea Field bog, the stratification is reversed, the much decomposed peat being at the surface and the slightly decomposed matter at the bottom. As to the hemicelluloses, cellulose, and lignin, the amount of these at first increases with depth but then decreases in the deeper, more mineralized layers. The profiles do not show any characteristic relationship between depth and the amounts of total ash and substances soluble in hot water. The amount of mineral matter in the two bogs is, moreover, particularly high even in the upper layers.

Certain chemical complexes brought to light by this analytical fractionation could be considered as a potential source of raw material for chemical industry. By means of continuous extraction it would, indeed, be possible to obtain from the two bogs studied the following quantities of chemical completes which could later serve in the fabrication of many fundamentally important products for industrial use.

112. Rochus, W. 1975. The organomineralic components in peat soils. In: Humus et Planta VI. Transactions of the International Symposium, Prague, August 18-25, 1975. pp. 141-148.

Organomineralic components were obtained from different soils and humic acids, silicic-humic acids and clay humus complex amounts were determined. Ten cultivated soils were found to have less content of humic acids than other soils studied but higher content of the other organomineralic components.

113. Rochus, W., and S.Sipos. 1976. Degree of humification and composition of the humus content from different low bogs. Proceedings of the 5th International Peat Congress, Poznań, Poland. September 21-25, 1976. Vol. 2: pp. 321-328.

Several decomposition degrees are used for characterizing peats. Each one is obtained by a specific method and none of them gives all the properties of peat as a whole. Especially for strongly decomposed low bog peats it is difficult to determine the degrees of decomposition and furthermore to compare the numbers found by using different methods.

Therefore, and to receive other peat determining data which can complete classical characterization, it is elaborated a simplified method using the humic substances, especially the humic acids, as indicators for the decomposition state of peats. These substances are the main constituents of the organic matter from investigated low bogs and for that reason suited to mark the humification degree of the peat and many of its properties.

By gradual extractions with aqueous acidic and alkaline solvents, fractions are prepared containing distinct groups of peat constituents suitable to characterize the humus complex by their amount, type, composition and properties. The fractions are analysed, listed and discussed. It could be confirmed that, using this method, it is possible to obtain data for a distinction also of strongly decomposed low bog peats. These data cannot be compared at once with the classical degrees of decomposition. Nevertheless the findings are appropriated to characterize different peats so much the more they are good reproducible and exactly appreciable.

114. Ruhling, A. and G. Tyler. 1971. Regional differences in the deposition of heavy metals over Scandinavia. J. Appl. Ecol. 8: pp. 497-507.

Metal concentrations of Hypnum cupressiforme, Hylocomium splendens and Sphagnum magellanicum from different parts of Scandinavia have been studied.

(1) The mean concentrations of Cd, Co, Cr, Cu, Ni, Pb and Zn in Hypnum cupressiforme from southern Sweden are larger in the south-west than in the north-east. The difference is highly significant for Pb, Cu and Ni.

(2) The concentration of Pb and Cd in Hylocomium splendens is more than ten times larger in south-western Sweden than in northern Norway and also for other heavy metals (except Mn) the differences are considerable. No differences between northern and southern Scandinavia in the concentrations of Ca, K and Mg have been measured.

(3) Heavy metal concentrations of Sphagnum magellanicum in ombotrophic bogland sites coincides well with the concentrations of Hyloccomium splendens from woodland sites of the same area. The deposition of heavy metals/hectare/year has been calculated.

The only probable explanation of the measured gradients is that the deposition of heavy metals, originating from human activity is much greater over southern Scandinavia, particularly south-western Sweden, than over northern Scandinavia. The regional 'basic concentrations' reported in this article reflect the fall-out from an atmospheric pool to which both neighbouring and remote sources contribute.

115. Sapek, A. 1976. Contamination of peat soils with lead and cadmium. Proceedings of the 5th International Peat Congress, Poznan, Poland. September 21-25, 1976. Vol. 2: pp. 285-294.

Lead and cadmium content from the upper horizon (Pb 10-60 ppm; Cd 0.15-0.16 ppm) and in profile samples from various organic soils was determined. In the upper horizon a significant negative correlation was found between ash and lead also between ash and cadmium ... a significant positive correlation was found between lead and cadmium. In the soil profile distinct differences in content of Pb and Cd were found also a positive correlation between the two was observed in the soil profile the content of Pb and Cd from the mineral fraction showed no distinct difference while the light fraction from upper horizon as compared with this fraction from the deeper horizon was richer in lead and cadmium than the whole soil. Atmospheric Pb and Cd may be the cause for this enrichment. It was supposed by the author that Pb and Cd contamination in peat soils run according to the same mechanism.

116. Sapek, A. 1975. Binding of lead by humic substances of peat soils In: Studies about humus. Transactions of the International Symposium, Humus et Planta VI, Prague, August 18-22, 1975. pp. 117-140.

Analyses of peat soils under the perennial grassland sward have proved a considerable accumulation of lead in upper horizon of these soils. On the peat bog Kuwasy, situatied at a long distance from industrial centres and large municipal agglomerations, in the soil horizon of 5-10 cm the lead concentration was found varying within 30-80 ppm, which is usually 10-40 times higher than the concentration of this element in the horizon of 40-50 cm. Lead is introduced into superficial soil horizons from the whole-world precipitation of dust and it can be presumed that this element would be bounded and retained in soil by humic substances.

The aim of the present work was to recognize the lead binding capacity of humic substances separated from peat soil with the purpose of determining the role of humic substances in behaviour of this element in soil.

117. Sapek, A. 1974. Lead and nickel content in peat soil profiles of the Kuwasy Bog. Proceedings of the International Peat Symposium, Gdańsk, Poland, 1974. pp. 174-185.

The behaviour of lead and nickel in peat soil profiles are studied. In other studies, these elements were found to be enriched in superficial soils. In the present study concentration of lead decreased with depth. This was thought likely to be due to world-wide fallout. Nickel was not found to accumulate in superficial soil layers.

118. Sapek, B., and W. Zebrowski. 1976. Comparison of copper binding rate by peat-muck soils at various transformation stages. Pol. J. Soil Sci. 9: 93-100.

The kinetics of copper binding by peat-muck soils at varous stages of transformation was investigated. Kinetic equations were adjusted to first and second order reactions to evaluate the differences in the rate of sorption by the soils. Two sorption phases were found to exist. The kinetic equation for the first order reaction described the second sorption phase with adequate approximation. Differences in the rate of copper binding by weakly, medium and strongly transformed soils were found.

119. Schallinger, K.M. 1972. 2nd Session, Group 3, Peat Chemistry and Physics. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. 5:61-65.

A short survey of 13 papers. Findings of peat as they now exist, additional uses, and problems that deserve further study were presented.

120. Schnitzer, M., and H. Kerndorff. 1981. Reactions of fulvic acids with metal ions. Water Air Soil Poll. 15: 97-108.

Fulvic acid is a water-soluble humic material that occurs widely in soils and waters and that tends to form water-soluble and water-insoluble complexes with a variety of metal ions, some of which are toxic. This paper presents information on the conditions under which the different types of FA-metal complexes are formed.

The solubility in water, separately and after mixing, of FA (2 to 30 mg/100 ml) and eleven metal ions (Fe(III), Al, Cr(III), Pb, Cu, Hg(II), Zn, Ni, Co, Cd, and Ma; 1 x 10^{-5} moles of each metal ion) was investigated over the pH range 4 to 9. After mixing, the solubility of the components was significantly affected by pH only when less than 20 mg of FA was present. As the systems became richer in FA (22 to 30 mg), most of the metal ions remained in the aqueous phase, likely due to the formation of FA-metal complexes, inhibiting the formation of metal hydroxides.

The order in which the eleven metal ions tended to form water-insoluble FA-metal complexes depended on the pH. At pH 6 it was: Fe=Cr=Al>Pb=Cu>Hg>Zn=Ni=Co=Cd=Mn. This order appeared to correlate with the valence, 1st hydrolysis constants and effective hydrated ionic diameters of the metal ions. In general, FA/metal weight ratios of > 2 favored the formation of water-soluble FA-metal complexes; at lower ratios, water-insoluble complexes, which could accumulate in soils and sediments, were formed.

121. Sillanpää, M. 1972. Distributions of trace elements in peat profiles. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol. 5: pp. 185-191.

Total contents of thirteen trace elements in two peat profiles are presented. The characteristics of their distribution within the profiles as well as the low contents of most elements in peats as compared with those in mineral soils are explained as a result of the element-lifting activity of plants.

122. Smith, D.G., and J.W. Lormier. 1964. An examination of the humic acids of Sphagnum peat. Can. J. Soil Sci. 44:76-87.

Humic and acid fractions were prepared by the repeated extraction of Sphagnum peat with dilute sodium hydoxide. The infrared spectra of the initial fractions were typical of humic acids. Spectra of the later fractions were indicative of an aromatic structure similar to that of lignin. Th content of methoxyl groups, which had remianed constant through the earlier fractions, increased rapidly in the later fractions. Changes in the intrinsic viscosity of the fractions in aqueous alkali and salt solutions paralleled those observed in the infrared spectra and methoxyl group content. The results show that humic acids of similar composition and increasing molecular weight were extracted initially, and that low molecular weight material resemgbling lignin predominated towards the end of the extraction. The presence of lignin was confirmed by alkaline nitrobenzen oxidation of a peat residue. Dilute sodium pyrophosphate extracted humic acids were obtained which were similar in all respects to the first fraction obtained by extraction with dilute sodium hydroxide.

123. Smith, D.G., C.Bryson, E.M.Thompson and E.G.Young. 1958. Chemical composition of the peat bogs of the Maritime provinces. Can. J. Soil Sci. 3:120-127.

The proximate chemical composition of seven peat bogs in the Maritime Provinces has been determined. The results have been expressed as profiles in relation to depth and as over-all averages for each bog.

The acidity tended to be high at pH 3.9-4.8; the moisture content was 90-95 percent; the total ash was low at 0.5-3 percent of which about 14 percent was CaO, 0.85 percent K_2O and 2.7 percent P_2O_5. Of the organic constituents the fraction containing waxes and resins averaged about 7 percent of the dry matter in most bogs. The total nitrogen was less than 1 percent. Hemicelluloses and other substances soluble in hot dilute HCl constituted 32-42 percent of the dry matter and humic substances 28-34 percent.

The process of humification was indicated by a decrease in cellulose, hemicelluloses and gums, and an increase in humic substances, waxes and resins.

124. Sowden, F.J., H.Morita, and M.Levesque. 1978. Organic nitrogen distribution in selected peats and peat fractions. Can. J. Soil Sci. 58:237-239.

The nitrogenous products formed by 6 N HCl hydrolysis of a variety of peats including a cultivated mesic profile, a virgin humic profile, a sedge, a woody and a sphagnum fibric peat were studied. Peat fractions separated according to particle size, woody and herbaceous materials isolated from a peat sample, and Typha and Carex plants growing on peat soils were also analyzed. Of the two profiles examined, the cultivated mesic peat showed significant quantitative changes in the content of individual amino acids throughout the profile. Also the amino sugar and amino acid N increased to a maximum, then decreased. On the other hand, the virgin humic peat profile exhibited random variations in the content of the individual amino acids and in the amount of amino acid N. Of the other peats examined, the fibric sphagnum had the highest percentage of amino acid N. Among the separates, the 100- to 200-mesh material had the highest proportion of amino acid N. The amino acid composition of the plant remains from the peat was similar to that of the peat from which it was isolated. The amino acid composition of the Typha and Carex plants was different from that of peat in that 75% of their total N content could be accounted for on the basis of amino acid, amide and amino sugar N. The amounts of hydroxyplroline and the amino sugars in peats vary more than that of the amino compounds. In contrast to inorganic soils, which tend to have a similar amino acid composition, these limited data suggest that the amino acid and amino sugar contents of peats may be characteristic of individual bogs.

125. Sparling, J.H. 1966. Studies on the relationship between water movement and water chemistry in mires. Can. J. Bot. 44: 747-758.

Fifty-four sites were selected in a number of mires in Ontario, and rates of water movement were measured on a number of occasions. The rates of water movement ranged from less than 0.1 cm/sec to over 8 cm/sec. The oxygen concentration of the mire waters increased with increasing flow rate, approaching saturation at rates over 1 cm/sec. From a model it was shown that at a flow rate of less than 0.3-0.4 cm/sec the diffusion of oxygen into the water would be similar to simple diffusion into a staionary water surface, and because of the respiration of roots and microorganisms in the peat, the oxygen would tend to be depleted. Above flow rates of 0.4 cm/sec the water is agitated, and is continually replenished with oxygen from the atmosphere. Reduced states of iron and manganese were shown to be in solution at concentrations greater than 0.1 mg/1 only at low rates of water flow. The pH was also shown to increase with faster rates of water movement, the increase depending on the base status of the mire. Auminum is in solution only in situations of low water movement where more acidic conditions are prevalent.

126. Steelnik, C. 1977. Humates and other natural organic substances in the aquatic environment. J. Chem. Ed. 54: 599-603.
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Functions of various natural organic substances are reviewed including metal transport, metal concentration, metal scavenging, growth regulation and sediment formation.

127. Stewart, J.M. and R.A. Robertson. 1968. The chemical status of an exposed peat face. Proceedings of the 3rd International Peat Congress, Quebec, Canada, August 18-23, 1968. pp. 190-194.

This paper presents the results of an exploratory investigation of the chemical analysis of 110 samples from an exposed peat face (120 cm x 400 cm) at Cruden Moss, Aberdeenshire.

The visible changes in the structure of the face can be explained most easily if the peat is regarded as a sequence of horizons derived from the pre-existing vegetation. Compressed aggregates of monospecific remains are scattered throughout the upper horizons and tend to concentrate certain elements, eg. silica in preserved *Eriophorum* tussocks.

The true status of chemical components in the peat face cannot be deduced from the analysis of a single profile because of the horizontal variation which occurs in the distribution of these elements. These variations are clearly indicated by the values obtained for carbon and nitrogen. A similar pattern was also observed for major inorganic components, namely, iron, sodium, potassium, magnesium; and calcium. The chemical composition of the peat samples does not appear to have been influenced by events on the hill site, except in the case of elements which can migrate more readily under reducing conditions.

Circulation of certain elements occurs in the surface peats due to adsorption by metabolically active root tissues. Biotic activity of surface flora and fauna also influence the distribution and availability of the biophilic elements of which phosphorous and sulfur are examples.

128. Tanskanen, H. 1976. Factors affecting the metal contents in peat profiles. *J. Geochem. Explor.* 5:412-414.

The effect of the four characteristic variables of a peat profile, that is, pH, degree of humification, percentage of ash and relative deplth, on the elemental abundances ina peat profile were kstudied. Each of ;them has different effects on different elements: Pb and Zn are closely related and so behave in an almost similar fashion; the same is trus of Cr and V, and Co and Ni, which likewise constitute pairs of analogous behaviour. In peat-geochemical studies the afore-mentioned variables must be kept in mind when considering the elemental abundances and their location.

129. Tanskanen, H. 1976. Rookkijärvi. The nickel/copper ratio in peat in a gabbro-periodotitic area. J. Geochem. Explor. 5: 309-310.

The nickel/copper ratio changes little with depth. Therefore the Ni/Cu ratio may be a better indicator of the underlying bedrock than either element alone.

130. Tarakanova, E.I. 1968. Minor elements in peat bogs in and beyond the central Urals. Translated from Litol. Pol. Isko. 2:136-140.

The peat ash from various deposits contains from 16 to 28 elements, frequently 20-25. The most diverse composition and highest concentrations of minor elements are confined as a rule to the peripheral areas of peat bogs and towards the base of the peat. In areas far from the bedrock, the number and concentratons of the minor elements are smaller.

131. Tarnocai, C. 1981. Soil and terrain development on the York factory peninsula, Hudson Bay Lowland. Paper presented at the Symposium on Hudson/James Bay, April 28-30, 1981. Proceedings in press. 22p.

The Hudson Bay floor is continuously being drained due to active glacial rebound (1.0-1.3 m per century). This provides a gradient for the observation of soil and terrain development, with relatively young soils and terrain types occurring close to the Hudson Bay shore and older soils occurring further inland. Five major processes - glacial rebound, coastal processes, fluvial processes, cryogenic or perma frost processes and peat-forming processes have been operating during the evolution of the terrain in the York Factory peninsula. As a result of poorly drained conditions and the development of permafrost, Gleysolic, Organic, and Cryosolic soil development are characteristic of thee area. The sequence of terrain types and associated soils that has developed from the coast toward the interior as a result of these processes is: low and high marshes and beach deposits with Rego Gleysols; alluvial plain with Rego Gleysol, peaty phase; horizontal fen, palsa fen and beaches with Terric Mesisols and Terric Mesic Cryosols; and peat plateau bogs and palsa bogs with Terric Mesisols and Terric Mesic Cryosols; and peat plateau bogs and palsa bogs with Terric Fibric Cryosols. The decrease in pH and calcium, magnesium, sodium and ash content in both soils and water and the increase in peat thickness and permafrost are associated with the soil development from the coast toward the interior.

132. Tarnocai, C. 1978. Genesis of organic soils in Manitoba and the N.W.T. In: Quaternary Soils - Third York Quaternary Symposium No. SRI 601, pp. 453-470.

Organic soil formation began several thousand years (4-6 thousand BP) after the glacial ice retreated from the continental portion of the study area. On the arctic islands, however, it began shortly after the glacial ice melted (8.5-9 thousand BP). These time differences are due to the fact that the climate was too dry and warm for organic soil formation on the continent while the cooler and moister climate of the arctic islands was much more favorable for peat deposition. The conditions for optimum organic soil development now occur in the boreal and subarctic regions where the climate is cool and moist.

Two basic processes have been identified as relating to the deposition of organic soil materials in the study area: the filling-in process is associated with shallow lakes where peat deposition slowly fills in the lake basin while the gradual build-up proces commonly ocurs on level and gently sloping areas.

Time is the dominant soil-forming factor and all other factors (climate, water properties, relief, vegetation and organisms) are time-dependent or sub-dominant factors. The interaction of the varous subdominant factors and time produces the individual organic soil layers resulting in the organic soil profile. The effects of time and the sub-dominant factors on the genesis of both the Organic and Cryosolic soils is discussed in detail in the paper.

The type of organic soil material (sphagnum, fen, forest, aquatic and mixed peats) resulting from the above processes will also be given along with the dominant organic soils belonging to the Organic and Cryosolic Orders.

133. Tibbetts, T.E. and J.A. Fraser. 1978. The utilization of Canadian peat as an alternative energy source. Canadian Mining and Metallurgical Bull., September 1978. 4 p.

In several European countries, including Russia, it has become economically attractive to utilize peat as a fuel for power generation, the production of metallurgical coke the production of fuel briquettes for the domestic market and low-Btu gas. Although the economic base and availability of energy supplies in Europe is much different than it is in Canada, regional economics here may warrant the development of peat as an alternative source of energy.

Canadian peatlands cover seveal thousands of square miles and have historically been considered as waste land. Now, with the increasing costs of other energy sources, it is apparent that fuel peat should be re-evaluated as a potential energy resource. A nation-wide inventory of peat deposits has been prepared and reserves evaluated for some of these areas where field surveys have been carried out.

The paper describes alternative mining methods developoed to meet some of the various conditions encountered on virgin peatland. These mining techniques are generally based on current peat technology exercised in other parts of the world and would be applicable in some of the peat regions of Canada.

134. Tibbetts, T.E. and A. Ismail. 1980. On the feasibility of mining peat for power generation in Canada. Canadian Mining and Metallurgical Bull. pp. 1-6.

The paper takes its material from three peat mining and power project feasibility studies sponsored by CANMET and conducted by Montreal Engineering Company Ltd. in the years 1976 to 1980. The role which peat may play in the Canadian energy prospectus is outlined estimated and measured fuel peat resources are tabulated, and the economic and technical feasibility of mining peat for power generation is reviewed.

135. Tolonen, K. and V. Hosiaisluoma. 1978. Chemical properties of surface water in Finnish ombrotrophic mire complexes with special reference to algal growth. Ann. Bot. Fennici. 15:55-72.

The relationship between 26 chemical and biological properties of mire water were studied in 51 mire complexes in Finland during the autumns of 1972-1974. Altogether 312 water samples were analysed.

The fen/bog limit - as determined in the field with vascular plant and moss indicators - was seldom clearly reflected in the concentrations of individiual chemical elements, but clearer differentiation was obtained when the chemical or biological parameters (particularly pH, Ca, Mg, Fe) were combined. The algal flora showed good correspondence with the water chemistry of the different hollow types. The average algal growth potential (AGP) recorded with Ankistrodismus falcatus (Corda) Ralfs and Selenastrum capricoinutum Printz was clearly higher in bog water than in fen water. In the former, AGP was near to that of mesotrophic lakes. The growth of Ankistiodesmus correlated best with the Cl concentration of the water.

136. Tolonen, K. and P. Seppänen. 1976. Comparison of ombrotrophic and minerotrophic mire waters in Finland. Proceedings of the 5th International Peat Congress, Poznan, Poland. September 21-25, 1976. Vol. 2: pp. 73-189.

Macro- and micro-nutrient and some liminological data from surface water samples of 51 mires of Finland were studied to determine the chemical background of the limit between ombotrophic bogs and minerotrophic fens.

Although there is a certain amount of overlap between the two, pool fen waters were found to be higher in pH and concentrations of Ca, Mg, Fe, Na, K, Cl, SiO , and Mn.

Positive correlation to the oceanity was indicated by distribution patterns of Cl, B, Na and Cu. The occurrence of molybdenum (in 1972 only) and sulfur in bog waters suggested a connection with air pollutants from Central Europe.

137. Tolonen, K., E.Raikamo, T.Lahti, and J. Viista. 1979. Siikaneva mire complex. International Symposium on Classification of Peat and Peatlands, Hyytiala, Finland-Excursion guide. September 17-21, 1979. International Peat Society.

Paper presents an overview of hydrology, vegetation, water and peat chemistry, peat resources, developmental history and bird fauna of the Siikaneva mire complex. Water and peat chemistry were in general agreement with results reported from Finand.

138. Tolpa, S. and E.Goroham. 1961. The ionic composition of waters from three Polish bogs. J. Ecol. 49: 127-133.

Analyses of major ions in the waters of three types of Polish *Sphagnum* bogs reveal slightly higher average concentrations of sulphuric acid than in the waters of floristically comparable ombrogenous bogs of the British Isles. The latter are, however, much richer in sodium chloride, as might be expected from their oceanic situation.

139. Tsaros, C.L. 1980. Peat dewatering, an overview. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1-3, 1980. pp. 181-195.

In order to effectively use peat, which contains 9 lb or more of water per lb of dry peat, most of the water must be removed without the use of fossil energy. Although most of the peat used today is air-dried, using solar energy this method is not feasible to supply the large amounts of energy needed for a typical substitute natural gas (SNG) plant because of the large area needed.

Mechanical dewatering to 70% moisture will remove most of the water in the peat. Thermal drying, with peat fuel, can be used to reduce moisture to below 50%. Use of: (1) rotary drum, (2)fluidized bed, or (3) flash dryers, all commercially available, is possible.

Other methods applicable to peat drying are the Carvery-Greenfield process and solvent dewatering. The former is basically a multiple-effect evaporation process using the fluidized-bed technique. The latter is based on the principle that in certain solvents the solubility of water changes substantially with change in temperature.

Wet carbonization, a beneficiation process, improves the dewaterability of peat. When wet peat is heated under pressure, eg. 500 psig at 400°/F, decarboxzylation and dehydration occur, resulting in a rise of unit heating value, with consumption of part of the total fuel value and production of gases and water-soluble organic chemicals. The product is mechanically dewatered to about 35% moisture.

There is little published information on the economics of peat dewatering. The estimated cost of dewatering by pressing and drying is at the level of 50 to 60¢/10^6 Btu.

Comparative economics for different methods of large-scale dewatering operations have not been published.

140. Urvas, L., M. Sillanpää, and R. Erviö. 1979. The chemical properties of major peat types in Finland. Proceedings of the International Symposium on Classification of Peat and Peatlands, Hyytiala, Finland, September 17-21, 1979, International Peat Society, 1979.

The results are reported of chemical analyses caried out on material consisting of 2418 samples of virgin peats taken from 806 sites in 14 soil survey areas. The sampling depths were 0-20, 20-40 and 40-60 cm. The material was divided into two major peat soil groups (*Carex* dominated and *Sphagnum* dominated), each group being divided into 4 subgroups.

The average pH (H O) of *Carex* dominated peats was 0.7 pH-units higher than that of *Sphagnum* peat soils. Also exchangeable calcium and potassium contents and total nitrogen content were noticeably higher in *Carex* peats than in soils dominated by *Sphagnum* peat. In contrast to these nutrients, soluable phosphorus content was lower in Carex than in *Sphagnum* dominated peat soils. On average, the C/N ratio was 23 in *Carex* dominated peats and 53 in *Sphagnum* peats.

In general, peat types classified previously on the basis of botanical composition and the "Degree of peat quality", indicating their suitability for agricultural properties, agreed well with the results reported here.

141. Verry, E.S. 1975. Streamflow chemistry and nutrient yields from upland, peatland watersheds in Minnesota. *Ecol.* 56:1149-1157.

Twenty-two water quality parameters were determined for the streamflow from complex but typical upland-peatland watersheds over a period of 5 years. Five watersheds with oligotrophic peatlands and one with a minerotrophic peatland were studied. Concentrations of organically derived nutrients are highest in the streamflow from watersheds containing oligotrophic peatlands; while concentrations of nutrients derived from solution of aquifer minerals are higher in streamflow from the watershed containing a minerotrophic peatland. However, flow-weighted concentrations of organically derived nutrients are similar for both watersheds.

Annual nutrient yields (kg/ha/yr) calculated for two of the tight upland oligotrophic peatland watersheds are generally low and are quite similar to values for other forested areas in North America which do not contain peatlands.

142. Volarvich, M.P., N.I.Gamayunov, and I.I.Lishtvan. 1972. Investigation of

physical and physico-chemical properties of peat. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol. 4, pp. 219-226.

This paper discusses modern notions of peat nature, aqueous, structural and ion exchange properties. The results of the tensimetric and calorimetric experiments to determine the forms and the energy of the bonds between moisture and peat are proved.

Mobility of water molecules upon peat was obtained by nuclear magnetic resonance technique.

The ion exchange of 800 peat samples was studied, the correlation between 35 indices of peat was found, thus making it possible to calculate the rest from only two of them.

Extensive rheological studies of peat were conducted. The mechanism of the electrolyte effect upon the structure forming process and stability of sod peat was studied.

143. Walmsley, M.E. and L.M.Lavkulich. 1975. Chemical, physical, and land-use investigations of organic terrain. Can. J. Soil Sci. 55:331-342.

Chemical and physical properties of selected organic soil samples were studied in relation to the chemical status of the associated ground water. Soil analyses included standard chemical analysis, fibre content, bulk density, particle density, hydraulic conductivity and water retention properties. In situ water chemical analyses included temperature, conductivity, dissolved oxygen and pH. Laboratory measurements of dissolved Ca, Mg, N, K, Si, NO_3, F, and Cl are also reported. The results are interpreted with reference to the surface expression and overall terrain morphology of the sampling area resulting in the formation of different peat types and associated vegetation. Physical and chemical data indicate a relationship between degree of decomposition and magnitude of various parameters. The distinction between bog and fen areas in terms of the level of dissolved electrolytes permits the prediction of the nature of the material comprising the organic soil. The distinctive properties of organic soils are discussed in terms of some use constraints imposed by the nature of the material in the context of aforestation of this terrain type.

144. Walters, A.B., R.J.King, and S.I.Richardson. 1980. Environmental issues and strategies for peat energy development in the U.S. In: Peat as an energy alternative. Proceedings of the Institute of Gas Technology Symposium, Arlington, Virginia, December 1-3, 1980. pp. 581-593.

The development of the U.S. peat energy resource requires special consideration of environmental laws and regulations unique to the U.S. Current international energy use of peat employs a variety of technologies and procedures that are adapted to the local peatlands, the local economics, and the local regulations of the foreign nations that use peat for energy. Environmental issues in the U.S., require peat energy development strategies that include modification of foreign technologies and procedures, new peat energy technologies, new environmental impact mitigation measures, and the revision of certain regulatory policies. Close cooperation between the states and the federal government, particularly the U.S. Department of Energy, and between potential peat energy developers and the various key Federal, state, and local regulatory bodies and private environmental protection organizations is essential to the timely implementation of peat energy projects.

145. Williams Brothers Engineering Co. 1979. Peat and the environment. In: Management assessment of peat as an energy resource. Proceedings of the Gas Technology Symposium, Arlington, Virginia, July 22-29, 1979. pp. 214-256.

This paper outlines the environmental, social, and economic effects of harvesting and gasifying peat on a commercial scale. Large-scale peat harvesting and gasification operations will affect the environment through the media of air, water, and land, but these impacts are controllable. In most instances, the environmental impact of commercial-scale peat gasification will actually be beneficial.

146. Yefimov, V.N. and Z.S.Yefimova. 1973. Chemical composition of bog water in the northwestern part of the European USSR. Translated from Sov. Soil Sci. 11:27-36.

Various aspects of the formation of the chemical composition of bog water in the northwestern part of the European USSR are examined. The mineral content of groundwater is shown to decrease from lowmoor to highmoor peat soils. Series of ions in the bog water of lowmoor, transition, and highmoor peat soils are presented. Calcium is shown to play a special role in bog soil formation.

147. Yliruokanen, I.D. 1976. Heavy metal distributions and their significance in Finnish peat bogs. Proceedings of the 5th International Peat Congress, Poznań, Poland. September 21-25, 1976. Vol. 2: pp. 277-283.

About 130 peat bogs in Finland have been surveyed for their inorganic components, especially heavy metals. The results show that it is reasonable to use peat for mineral prospecting especially in Finland where 25% of land area is bog. Since peat is used in increasing amounts as a fuel its heavy metal content is of considerable importance. On the one hand peat may cause air pollution when burned or its ash become a disposal problem; on the other hand the ash maybe a useful raw material. (Ni, Cu, Zn, As, Pb and U - metals studied)

148. Ziechmann, W. and B. Kress, 1972. Physical-chemical investigations for description of structure and mode of interaction of humic substances. Proceedings of the 4th International Peat Congress. Otaniemi, Finland, June 25-30, 1972. Vol. 4, pp. 87-93.

Information was sought with respect to the construction and reactive behaviour of humic substances in connection with spectroscopic and thermodynamic measurements. The relationship between the structure of the substance and its energy state are especially important to the investigations of strucrute and modes of interaction.

6.2 ADDITIONAL ABSTRACTS

149. Gemell, D.E. and D. Keys. 1979. Evaluation of the New Brunswick peat resource. Canadian Peat Symposium, Fredericton, New Brunswick.

There are in excess of 100,000 hectares (250,000 acres) of peatlands in New Brunswick. Approximately 80% of these are underlain by flat-lying sandstones of Carboniferous age in the eastern and central areas of the province. These bogs are found mainly along the coast or in divide areas between river systems. The bogs in the northeastern region are the best known for two reasons; the horticultural peat industry began in this region in 1942, and the provincial survey commenced in this region in 1975. However, the northeast region only represents 18% of the total peatlands.

Past work carried out in the province began in 1900. Ganong reported on New Brunswick's bogs at that time followed by Anrep in the 1920's, Auer in the 30's and Leverin in the 40's. Their investigations of various bogs were carried out with a view to utilization for peat moss, litter, and as a source of fuel. A. Spence and others with the New Brunswick Department of Natural Resources did field work on request basis in the 50's, 60's and early 70's dealing mainly with horticultural uses. Researchers associated with the biology and engineering faculties of the University of New Brunswick and the Muskeg Research Institute carried out detailed investigations in several areas of the province.

150. Jeglum, J.K. 1971. Plant indicators of pH and water level in peatlands at Candle Lake, Saskatchewan. Can. J. Bot. 49: 1661-1676.

Quantitative data on vegetation, depth to water level, and pH of both moist peat and water from 113 stands of peatland near Candle Lake, Saskatchewan, are used to demonstrate relationships of peatland species to classes of pH and depth to water level, and to recognize plant indicators for the various classes. Weighted average and similarity coefficient techniques are used to estimate pH and depth to water level from total species lists and restricted lists of important species. Total species lists, combined with either weighted average or similarity coefficient techniques, yield indices with the highest correlations with the true values and the lowest standard errors of estimate. Depth to water level and pH are recognized as two important environmental correlates with floristic and vegetational variation in peatlands.

151. Pollett, F.C. 1972. Nutrient contents of peat soils in Newfoundland. Proceedings of the 4th International Peat Congress, Otaniemi, Finland, June 25-30, 1972. Vol. 3: 461-468.

The nutrient status of peats underlying the six major plant associations characterizing most bogs and fens in Newfoundland is assessed quantitatively. Mean total and available N, P, K, Ca, Mg, Mn, Fe and Zn concentrations, expressed by dry weight are given, as well as mean pH values and ranges of bulk density, humification and water content.

It was found that the plant associations, as detected through the Z - M classification, reflects the pH and concentrations of total N, Ca, Fe, and available Ca.

To provide a measure of the afforestation potential of the peats nutrient contents were expressed in kg/ha for a 20 cm surface peat layer from each site type. The poorest bogs contain 370 - 1590 N, 28 - 94 P and 25 - 112 K, whereas the rich fen peats contain 3470 - 8910 N, 94 - 379 P and 86 - 324 K.

152. Singhroy, V. 1980. Annotated bibliography on fuel peat. Prepared for Lands Directorate Environmental Management Service, Environment Canada, Halifax, Nova Scotia. 199 p.

This bibliography contains a selection of entries related to fuel peat. The report is divided into two sections. Abstracts dealing with general environmental concerns of utilizing peat as fuel are found in Section 1. Methods of production and utilization are dealt with in Section 2.

153. Smith, D.G., C. Bryson, E.M. Thompson and E.G. Young. 1958. Chemical composition of the peat bogs of the Maritime Provinces. *J. Soil Sci.* 38: 120-127.

The proximate chemical composition of seven peat bogs in the Maritime Provinces has been determined. The results have been expressed as profiles in relation to depth and as over-all averages for each bog.

The acidity tended to be high at pH 3.9-4.8; the moisture content was 90-95 per cent; the total ash was low at 0.5-3 per cent of which about 14 per cent was CaO, 0.85 per cent K_2O, and 2.7 per cent P_2O_5. Of the organic constituents the fraction containing waxes and resins averaged about 7 per cent of the dry matter in most bogs. The total nitrogen was less than 1 per cent. Hemicelluloses and other substances soluble in hot dilute HCl constituted 32-42 per cent of the dry matter and humic substances 28-34 per cent.

The process of humification was indicated by a decrease in cellulose, hemicelluloses and gums, and an increase in humic substances, waxes and resins.

154. Stanek, W. 1976. Annotated bibliography of peatland forestry. Environment Canada Departmental Library. Bibliography Series; 76/1. 205 p.

This annotated bibliography contains 598 entries from European, North American and USSR sources on peatlands and their utilization for forestry purposes. Included is a compendium dealing with peatland classification, water relations, drainage, silviculture, nutrient content of peat and trees growing on peatlands, fertilization, economics of drainage, and effect of drainage upon wildlife. The references are listed by subject in a subject index.

155. Stanek, W. and J.K. Jeglum. 1977. Comparisons of peatland types using macro-nutrient contents of peat. Vegetatio 33: 163-173.

Vegetation formations (BOG, FEN-MARSH, and SWAMP) and types within formations for the Northern Clay Section of Ontario were compared on the basis of the quantities of five macro-nutrients in their peats: N, P, K. Ca, and Mg. The comparisons revealed that the formations, except FEN and MARSH, are clearly distinguishable on this basis. Heterogeneity between formations or between some of the types within formations, and trends in statistical indices for sequences of types, suggested that the original classification of Jeglum et al. (1974) based on vegetation conveys reliable information about soil nutrient contents.

156. Stanek, W. and T. Silc. 1977. Comparisons of four methods for determination of degree of peat humification (decomposition) with emphasis on the von Post method. Can. J. Soil. Sci. 57: 109-118.

The degree of decomposition (humification) of 10 peats, ranging from undecomposed to completely decomposed, was determined by the following methods: von Post's method using 10 classes of humification, pyrophosphate--soluble organic matter determination using an index derived from Munsell color charts, unrubbed fiber content in percent of total, and rubbed fiber content in percent of total. All 4 methods provided reliable and useful information. The von Post method required no instrumentation and was most suitable for field use. It was the least time-consuming and the cheapest of the 4 methods. The pyrophosphate method was best suited to use in a laboratory. It did not always readily differentiate grades of well humified and completely humified peats. Both methods for determining fiber content required instrumentation and a steady, running stream of water. The rubbed fiber content more accurately characterized the amounts of undecomposed fiber in peat. In the range of humic peats the 2 latter methods tended to differentiate fewer classes than did the von Post method.

157. Wells, E.D. 1981. Peatlands of eastern Newfoundland: distribution, morphology, and nutrient status. Can. J. Bot. 59: 1978-1997.

The peatlands of eastern Newfoundland are classified into six morphological types: domed bog, blanket bog, slope bog, basins bog, ribbed fen, and slope fen. The separation of types is based on peat depth, surface physiognomy and slope, underlying basin or slope morphology, botanical constituents, and degree of humification of the peat strata. Low elevation aerial oblique photographs and stratigraphical profiles of the six representative morphological peatland types are presented.

The peatland vegetation is classified into eight associations and four pool communities; three alliances are also proposed and comparisons with syntaxonomical classifications of European peatlands are discussed. Phytosociological tables are presented for the dry bog vegetation, wet bog vegetation, and fen vegetation; a summary table showing differential species groups of each syntaxon is also presented. pH and total contents of nitrogen, calcium, and iron are determined for the major vegetation types.

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POOR

QUALITY

ORIGINAL